Assessing efficiency drivers in municipal solid waste collection services through a non-parametric method

Andrea Guerrini [a, *], Pedro Carvalho [b, c], Giulia Romano [d], Rui Cunha Marques [c], Chiara Leardini [a]

[a] Verona University—Department of Management, Via dell'Artigliere, 19, 37129, Italy
[b] Modelling Methods in Engineering and Geophysics Laboratory (LAMEMO), Department of Civil Engineering, COPPE, Federal University of Rio de Janeiro, Av. Pedro Calmon - Ilha do Fundão, 21941-596, Rio de Janeiro, Brazil
[c] CESUR-CERIS, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais, 1049-001, Lisbon, Portugal
[d] University of Pisa—Department of Economics and Management, Via C. Ridolfi, 10, 56124, Pisa, Italy

ARTICLE INFO

ABSTRACT

Municipal solid waste collection is a public service with impact on the environment, public health, and the appearance of a municipal area. The standard of efficiency achieved in providing this service has a direct impact on household expenditure, since the costs of collection are recovered through citizens' taxes. The failure to consider relevant performance drivers recently led some Italian waste utilities into bankruptcy and financial collapse. Following prior research to identify the environmental and operational variables affecting the efficiency and quality of waste collection services, this study applies a more suitable and robust non-parametric method based on conditional order-m efficiency to identify the performance drivers of the waste collection services in 40 municipalities in Verona province, Italy. The exogenous variables studied could be clustered as 1) customer features (size of population served, population density, tourist flows, and percentage of non-residential customers; 2) household features, measured by number of inhabitants per house; and 3) operational features, represented by tons of waste collected for each load, method adopted (curbside or street bin), and maturity achieved with a given method. The study demonstrates that all variables affect the cost efficiency of waste collection with different intensity and direction.

1. Introduction

In recent years, significant changes in municipal solid waste (MSW) management have occurred due to demographic evolution and economic growth. In developed countries, like Italy, the amount of waste produced annually by each citizen increased 22% in a decade, rising from 449 kg in 1995 to 552 kg in 2006 (ISTAT, 2013). The increase in waste generated has instigated calls for wide reforms of the sector, in order to improve the process of waste management.

The European Union (EU) intervened with legislation to regulate the waste sector, promoting separate curbside collection of recyclables and residual waste. Additionally, while the EU has been moving away from landfill disposal towards recycling and reuse (Waste Framework Directive 2008/98/EC), the focus in lower-income countries around the world has been more on how to improve coverage of services (Filho et al., 2016). Considering the scarcity of resources affecting the public sectors and their budget constraints, which are tighter because of EU agreements, municipalities might follow three policies to obtain the funds required to achieve higher quality standards: 1) improve taxes and tariffs; 2) obtain further resources from banks and private investors increasing the indebtedness; and 3) improve efficiency in service provision. The first option is quite unpopular and contrasts with the aim of politicians to be re-elected; furthermore, it can be pursued only if authorized by local authorities and by the concession contracts that locally regulate waste services. The collection of resources from private institutions and investors is not always feasible for different reasons (e.g. higher costs paid by citizens, low rate of investment return, and information asymmetry between

concessionary and municipality). While in several European countries, MSW management has been entrusted to public-private partnerships or to privately owned firms, other countries have recently re-nationalized MSW services (e.g., France, the UK, Germany).

Thus, the third alternative could be the best one for final customer. Increasing cost efficiency and maintaining quality standards are typically among the options under discussion by municipal policymakers.

A literature review of the efficiency of MSW management (e.g., De Jaeger et al., 2011; Jacobsen et al., 2013; Simões et al., 2010, 2012) shows that collection costs could be affected by many factors, such as population features (size, density, age, and tourist flows); geographical characteristics; household features; quantity and quality of waste generated; distance from collection points to places of disposal; and method of collection (street bins or curbside).

Building from the most recent studies (Agovino et al., 2016; Greco et al., 2015; Simões et al., 2012), this article shows how environmental and operational variables affect the efficiency of collection services in Italy, observing data from 2008 to 2012 of 40 Italian municipalities located in the northeast of the country.

The objective of this study is to identify the performance drivers that should be monitored by policymakers and managers in order to improve efficiency and safeguard service quality.

The main problem in efficiency measurement is the construction of the efficiency frontier and identification of the exogenous variables affecting it. Prior studies could be clustered according to the method adopted for efficiency measurement. A first group adopts a parametric approach that makes assumptions about the parameters of the population distribution from which data are drawn (i.e., Callan and Thomas, 2001; Gellynk and Verhelst, 2007; Simões and Marques, 2011). Others adopt a non-parametric approach, which requires no assumptions about the functional relationship between costs and outputs, and uses data related to multiple inputs and outputs (i.e., De Jaeger et al., 2011; Marques and Simões, 2009; Worthington and Dollery, 2001). Both alternatives are based on a two-stage procedure: measuring efficiency scores in the first stage and then relating them to explanatory variables. This procedure has been criticized (Simar and Wilson, 2004; 2007) for failing to account for serial correlations in the efficiency score. Then, it requires a restrictive separability condition between the input–output space and the environmental factors space. The separability condition means that the exogenous variables do not exert any effect on the frontier of full efficiency, but may influence only the distribution of the efficiency scores (Wang and Schmidt, 2002; Badin et al., 2010).

Since both approaches have some limitations, the main contribution of this study is its adoption of a more suitable method to investigate the influence of operational and environmental variables on MSW services (Simões et al., 2013). The method chosen is based on a conditional efficiency model (Cazals et al., 2002; Daraio and Simar 2005) which uses exogenous variables to group observations and then, to estimate efficiency scores, avoiding the drawbacks of previous research arising from bias due to the correlation between exogenous variables and input and output used to estimate efficiency.

The rest of this paper is organized as follows. Section 2 gathers evidence from prior literature focused on performance drivers in waste collection. Section 3 describes the market structure and regulatory framework of the Italian waste sector. Section 4 discusses the method adopted to estimate efficiency and its determinants, followed by Section 5 with a description of the main characteristics of the selected municipalities. Section 6 shows and discuss the main results, while Section 7 contains concluding remarks and some policy implications.

2. Prior evidence on performance drivers in waste collection services

Similar to other public services (e.g., water, energy, and gas), MSW has been studied to observe the determinants of cost variation, considering environmental and operational variables (De Jaeger et al., 2011; Jacobsen et al., 2013; Simões et al., 2010, 2012). To improve efficiency, public utilities have various choices, including technological innovations, staff training, improved procurement policies, and the development of an internal control system dedicated to attain effective and efficient corporate processes. Other choices usually depend on the context in which the utility operates, which means that they cannot be fully controlled by firm managers and owners in the short term. These choices include the scale of the firm, degree of investment diversification and vertical integration, population density, and demographic characteristics (for water utilities, see Berg and Marques, 2011; for gas distribution, see Hollas et al., 2002; for electric retail services, see Kumbhakar and Hjalmarsson, 1998).

In contrast to the water sector, the literature on MSW is widely fragmented (see Simões and Marques, 2012 for an extensive literature analysis). Many authors have studied the effects of numerous variables on efficiency, although the only factor that appears to have been studied extensively is ownership structure. The literature on MSW contains examples of the advantages and disadvantages of privatized waste utilities; however, as in line with other public services, these results do not converge (Simões et al., 2012). Some authors have found that private participation is beneficial in the provision of waste management services because utilities are no longer under the control of politicians, and incentive mechanisms can be adopted to improve efficiency. These incentives can include performance evaluation, internal auditing, and human resource management (Berenyi and Stevens, 1988; Cubbin et al., 1987; Domberger et al., 1986; Jacobsen et al., 2013; McDavid, 1985; Savas, 1974; Szymanski, 1996; Szymanski and Wilkins, 1993). Other studies have been inconclusive (Callan and Thomas, 2001; Collins and Downes, 1977; Garcìa-Sànchez, 2008; Hirsch, 1965; Simões et al., 2012) or have supported public ownership as a determinant that positively affects cost savings (Benito et al., 2010; Ohlsson, 2003; Pier et al., 1974).

Studies focusing on other operational and environmental variables have found a wide range of results. For example, population density is a relevant environmental variable that may affect waste utilities performance. Population density can be measured by the ratio of number of inhabitants per square kilometers of the served area. Some studies have argued that the higher the density is, the higher are cost savings because there are more tons collected at each pickup point (Callan and Thomas, 2001; Carroll, 1995; Dubin and Navarro, 1988; Koushki et al., 2004). Recently, other studies have demonstrated that this variable actually damages efficiency (Benito et al., 2010, 2011; De Jaeger et al., 2011; Vishwakarma et al., 2012; Worthington and Dollery, 2001) because narrow and densely populated streets can reduce the possibility of using large and specialized equipment. Thus, this equipment must be replaced by less productive manual activities, which means that the effect of congestion offsets any cost saving attained by covering shorter distance among pickup points. In addition, according to Passarini et al. (2011), these characteristics appear to affect the rate of separate collection negatively, which is higher in the rural area of Emilia Romagna, with a low population density, than elsewhere in the same Italian region. Finally, Simões et al. (2012) demonstrated