Omega 41 (2013) 653–664

Contents lists available at SciVerse ScienceDirect

Omega

journal homepage: www.elsevier.com/locate/omega

Measuring and explaining the cost efficiency of municipal solid waste collection and processing services

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ARTICLE INFO

Article history:
Received 17 January 2012
Accepted 20 September 2012
Processed by B. Lev
Available online 28 September 2012

Keywords:
DEA
Efficiency
Environmental studies
Policy analysis

ABSTRACT

This paper proposes an adjusted version of the popular efficiency measurement technique data envelopment analysis (DEA) that makes it possible (1) to evaluate the cost efficiency of municipalities in the collection and processing of multiple household waste fractions, (2) robustifying the cost efficiency evaluations for the impact of measurement errors in the data or municipalities with outlying and atypical performances (if present in the sample set), and (3) to correct the evaluations for differences in the operating environments of municipalities (e.g., factors such as demography and median income of the municipality population). The paper illustrates the usefulness of the methodology by carrying out and analyzing a cost efficiency evaluation using data on 293 municipalities in Flanders, Belgium, for the year 2008.

1. Introduction

The growing focus on municipal solid waste (MSW) reduction, re-use and recycling by international, national and regional governments has prompted important reforms in local/municipal waste collection and processing policy. As it is often at the local level that higher order policy initiatives are operationalized, municipalities are increasingly subjected to intricate waste collection and processing systems. In addition, municipalities are ever more challenged to create a sound budget without raising the tax burden or cutting the provision of these vital services to the residents. Fuelled by this evolution and supported by methodological innovations, a growing number of studies aim at assessing the efficiency of local MSW collection and processing services. Nevertheless, capturing the full complexity of MSW services when analysing the cost efficiency of municipalities proves to be a tortuous matter, as important conceptual and methodological difficulties are often neglected in the existing literature. In this paper we draw upon recent developments in the efficiency literature in order to provide an answer to three of those conceptual and methodological issues.

The first important issue is related to the peculiar role that the input 'waste cost' is playing in the municipalities' collection and processing efforts of the different MSW fractions. Municipalities use public resources to manage and finance the collection and treatment processes of the various fractions of MSW. It is therefore particularly interesting for the municipalities to have an idea not only about aggregate cost efficiency, but also about the cost efficiencies realized in the collection and treatment of the each waste fraction separately (i.e., partial cost efficiencies). Of course, the estimation of partial cost efficiency measures requires detailed information on how costs are precisely shared between the different MSW fractions. However, such detailed information is typically lacking. Previous studies that focused on the cost efficiency of municipalities used the basic DEA-model that does not explicitly account for this peculiar role of the input 'waste cost'. Consequently, these studies were only able to compute a global cost efficiency measure for the municipalities and not detailed partial cost efficiency measures.

A second issue in the cost efficiency evaluations of the municipalities involves correcting for the impact of the operating environment. The basic DEA-model presumes that all municipalities are homogeneous in the sense that they perform similar activities under comparable operating circumstances. Critical readers would remark that this assumption of "operating under comparable circumstances" is hard to maintain in practical settings. Both the empirical results in the literature (for an overview, see Section 2) as well as the practical experiences of the people that are active in this business (for instance, policy makers at the municipal level, administrators in government institutions-like OVAM in Flanders, etc.) suggest that some operating environments are more beneficial to cost efficiency in the collection and treatment of MSW waste, while other operating

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http://dx.doi.org/10.1016/j.omega.2012.09.006

environments make it more difficult for a municipality to operate cost efficiently.

A third difficulty is related to the DEA-model itself, and more particular to the relative perspective that is used by this model in the estimation of the cost efficiencies. The DEA-model relates the cost and waste quantity data of each evaluated municipality in a relative perspective to the cost and waste data of the other municipalities in order to evaluate the assessed municipality's aggregate and partial cost efficiencies. This relative perspective means that the presence merely of one municipality in the data set with outlying and/or atypical cost and waste data suffices considerably to impact the cost efficiencies of all municipalities in the dataset. That is to say, the basic DEA-based estimates are non-robust in the sense that they are sensitive to the impact of such municipalities. A correction of the DEA-model such that cost efficiency estimates are less sensitive to such influences would clearly benefit the reliability and validity of the DEA-model in evaluating municipality cost efficiency.

The main objective of this paper is to adjust the DEA-model so that it provides answers to the three conceptual and methodological problems raised. In particular, this paper develops and advocates a robust and conditional version of the shared input DEA-model in evaluating the cost efficiencies of Flemish municipalities in the collection and treatment of MSW. This model is based on recent additions to the DEA-literature (i.e., the ideas of the shared input DEA-model follow Beasley [2], Cook et al. [10], and Cook and Green [9], whereas the additions to the robust and conditional DEA-model follow, among others, Cazals et al. [7], Daraio and Simar [11–13], and De Witte and Kortelainen [18]). As we will argue, introducing this format of DEA when analyzing the cost efficiency of MSW related services, enables us to (1) compute partial cost efficiency measures for each waste fraction; (2) mitigate the impact of municipalities with outlying or atypical cost and quantity data; (3) correct for the impact of the operating environment and policy variables which are only controllable to the municipalities in the long term, and (4) analyze the way in which the characteristics of the operating environment are precisely related to the municipalities' cost efficiency in MSW collection and processing. No doubt, such knowledge is informative and useful for both municipal and regional policy makers.

This paper unfolds as follows. The next section provides a brief literature review of previous DEA-studies in the waste management literature. The focus is on studies that examined the efficiency measurement of municipalities as well as on studies that discussed the question of how the operating environment may affect the municipalities' efficiency. In a third section, we discuss the household waste cost and quantity data for Flemish municipalities for the year 2008. Section 4 presents the robust and conditional version of the shared input DEA-model. In Section 5, we present and analyze the cost efficiency evaluations for the Flemish municipalities. In particular, we focus on the impact of the operating environment and long-term policy variables on the outcomes of our efficiency evaluation. In a final section, we make some concluding remarks and provide some directions for further research.

2. Literature

A growing body of research aims at measuring and explaining municipality efficiency in the collection and processing of household waste. Efficiency in this context refers in general to the relation between (minimal) inputs and (maximal) outputs. The choice of the inputs depends on the exact efficiency concept under consideration. For instance technical efficiency refers to the relation between physical inputs such as number of garbage trucks or the number of workers, and the level of the outputs (examples include [5] or [22]). When the focus lies on cost efficiency, inputs usually correspond the costs incurred for providing the MSW service (see, for instance, [42] and [31]). Although some exceptions exist, in general the outputs are expressed in the amount of waste collected and/or processed. Next to inputs and outputs some authors account for the non-homogeneous nature of municipalities in terms of background conditions by including environmental variables. These are variables that can be considered non-discretionary in the sense that they are not controllable by the municipalities, at least not in the short term.

In what follows, as a background to this study, we briefly outline some of the insights of previous studies. Note that it is not our intention to give a complete overview of the literature, but rather to provide the reader with some key insights deemed to be relevant for the remainder of this paper. Considering that a correct identification of relevant background variables is critical for our empirical assessment, the next two sections present a brief overview of the environmental variables most accounted for in the literature. We make the distinction between environmental variables that identify the operating environment (Section 2.1) and long-term policy variables which can only be considered as environmental in the short term (Section 2.2 Long-term policy variables). Note that only a few studies incorporate environmental variables in a nonparametric efficiency analysis. Therefore, we also draw from parametric studies analyzing the impact of environmental variables on the municipalities' waste costs rather than the cost efficiency.[1]

2.1. Operating environment

According to Bello and Szymanski [4] or García-Sánchez [22], typical environmental variables that could influence the efficiency of waste collection and processing services are the municipality's demographic and socio-economic characteristics. Background characteristics most accounted for in the literature are population size and/or population density (examples include [31,30] and [17]) or, closely related, the number or density of pick-up points (see, for instance, [41,4,22]). The impact of population size on efficiency scores is generally believed to be positive (see, for instance, [27] or [22]). Debate on the impact of population density (or density of pick-up points), however, is still on-going. On the one hand, a high population density reduces the time needed to drive from pick-up point to pick-up point; which in turn could reduce the input requirements (see, for instance, [22,26,24]). On the other hand, as argued by Worthington and Dollery [42], congestion and other difficulties encountered in densely populated areas (such as narrow streets or on-street parking) could place constraints on operating collection machinery. The latter observation seems to be in line with the situation in Flanders as the results of De Jaeger et al. [17] indicate that the population density has a negative impact on the cost efficiency score of Flemish municipalities.

Besides population related variables some authors include income (or GDP) per capita as an environmental variable. Theoretically the relation between income per capita and cost-efficiency is believed to be positive (see, for instance, [24]), however empirical proof of such a relation is less common. García-Sánchez [22] and De Jaeger et al. [17] found that income per capita cannot explain the level of efficiency attained by the municipalities, while Marques and Simões [31] only report a

[1] Note that, although both concepts (costs and efficiency) are closely related, potential costs drivers are not always detrimental to efficiency scores (see infra).