Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

Does recyclable separation reduce the cost of municipal waste management in Japan?

Rosaria Chifari [a,1], Samuele Lo Piano [a,1], Shigeru Matsumoto [b,1,*], Tomohiro Tasaki [c,1]

[a] Institute for Environmental Science and Technology, Universitat Autònoma de Barcelona, Edifici Z, 08193 Bellaterra, Cerdanyola del Vallès, Barcelona, Spain
[b] Department of Economics, Aoyama Gakuin University, Room 828 Building 8, 4-4-25 Shibuya, Shibuya, Tokyo 150-8366, Japan
[c] Center for Material Cycles and Waste Management Research, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan

ARTICLE INFO

Article history:
Received 17 October 2016
Revised 11 January 2017
Accepted 11 January 2017
Available online xxxx

Keywords:
Municipal solid waste management cost
Japan
Source separation
Treatment stage

ABSTRACT

Municipal solid waste (MSW) management is a system involving multiple sub-systems that typically require demanding inputs, materials and resources to properly process generated waste throughput. For this reason, MSW management is generally one of the most expensive services provided by municipalities. In this paper, we analyze the Japanese MSW management system and estimate the cost elasticity with respect to the waste volumes at three treatment stages: collection, processing, and disposal. Although we observe economies of scale at all three stages, the collection cost is less elastic than the disposal cost. We also examine whether source separation at home affects the cost of MSW management. The empirical results show that the separate collection of the recyclable fraction leads to reduced processing costs at intermediate treatment facilities, but does not change the overall waste management cost. Our analysis also reveals that the cost of waste management systems decreases when the service is provided by private companies through a public tender. The cost decreases even more when the service is performed under the coordination of adjacent municipalities.

1. Introduction

Issues of solid waste management are expected to become a major environmental problem in the near future for cities worldwide (Saeed et al., 2009). For instance, the World Bank (2012) expects the volume of waste globally generated in urban contexts to increase from the 2009 annual figure of 1.3 billion tons to 2.2 billion tons in 2025.

In recent years, the majority of municipalities in developed countries have implemented various forms of programs and schemes to promote waste reduction activities. Some municipalities have developed recycling programs to collect recyclable materials from trash while also enhancing nutrient recovers from biodegradable waste (Zabaleta and Rodic, 2015). Others municipalities have adopted pay-as-you-throw programs to educate residents on the costs of waste disposal (Kinnaman, 2006; De Jaeger and Eyckmans, 2015) and to promote community efforts towards waste-throughput reduction (Castagna et al., 2013; Di Leo and Salvia, 2017). Although it is known that traditional reuse practices have helped save substantial amounts of reusable resources (Bari et al., 2012), municipalities in developing countries have started implementing waste management programs analogous to those used in developed countries (Troschinetz and Mihelcic, 2009; Sarkhel et al., 2016) due to a shortage of waste-treatment capacities.

Despite the development of the above-mentioned waste reduction and recycling programs, solid waste management schemes can still be listed as some of the most expensive services provided by municipalities. In low-income countries, public spending on this service typically amounts to 20–50 percent of the recurrent available budget (World Bank, 2011). The allocation of such a relevant fraction of public resources makes it difficult for these countries to address citizens' remaining basic needs. In such stressed financial conditions and in view of increasingly aging population-driven social security expenditures, the reduction of MSW management costs is becoming a major policy challenge for developed countries.

The MSW management cost structure has been frequently analyzed in the literature. However, we believe there are at least two limitations to previous studies. First, the ways in which waste separation affects costs of MSW management have not been examined; second, cost elasticity with respect to waste volume at the collection, processing, and disposal stages has not been adequately covered. With the aim of addressing these two research gaps, we

* Corresponding author.
E-mail address: shmatsumoto@aoyamagakuin.jp (S. Matsumoto).
[1] The list of authors is alphabetical and reflects equal contribution.

http://dx.doi.org/10.1016/j.wasman.2017.01.015
0956-053X/

Nomenclature

Roman symbols

Q_T	quantity of total waste reported in the survey [ton]
Q_R	quantity of waste adjusted for costs of treatment [ton]
A	constant [–]
L	total quantity of labor inputs [–]
K	total quantity of capital inputs [–]
w	wage [–]
r	rental cost of capital [–]
C_T	total cost of waste management [thousands of dollars]
C_C	cost at collection stage [thousands of dollars]
C_P	cost at processing stage [thousands of dollars]
C_D	cost at disposal stage [thousands of dollars]
c_0	constant [thousands of dollars]
c_1	cost elasticity with respect to wage [%]
c_2	cost elasticity with respect to the quantity of total waste [%]
$\boldsymbol{X}$	vector of control variables [–]
$\boldsymbol{B}$	vector of the coefficient for control variables [–]
k	waste category [–]
m	total number of waste categories [–]

Greek symbols

α	labor coefficient in the Cobb-Douglas production function [–]
β	capital coefficient in the Cobb-Douglas production function [–]
s_k	share of the k^{th} category of waste [0–1]
θ_k	cost elasticity with respect to the waste share [%]

analyze the Japanese MSW management system in this study. The case of Japan is particularly suitable to study as all Japanese municipalities file their waste management information in a specified and standardized format reported annually to the central government. This standardized data collection system allowed us to carry out a cost structure analysis in a systematic manner. To this extent, we believe that our empirical results could prove useful not only for MSW management planning in Japan but also for such planning in other countries. By analyzing cost variations of each parameter, it is possible to plan the most relevant course of action needed to lower management costs. Such an approach could prove particularly useful for policy makers when planning local management systems.

The remainder of the paper is organized as follows. Section 2 reviews the empirical findings of previous studies. In Section 3, we summarize the data used and described the waste management system in Japan. In Section 4, we specify our empirical models. Section 5 presents the empirical results of our statistical analysis. Section 6 reports our conclusions and policy implications.

2. Literature review

The MSW management cost structure has been analyzed in the literature for the last 50 years due to its significance and to its specific importance to overall systems planning. Table 1 summarizes the empirical findings of the nine most-frequently cited articles in scientific journals written on this subject.

The table presents geographic information and the size of each municipal sample examined in each study. Each row represents factors taken into account to determine their influence on the overall costs of municipal solid waste management schemes.

Hirsch (1965) initiated a study on MSW disposal by analyzing data from 24 municipalities in the St. Louis county area in 1960. Since then, other early studies such as Kitchen (1976), Stevens (1978) and Dubin and Navarro (1988) have been conducted in North America. In contrast, more recent studies have been performed in European countries (Italy (Greco et al., 2015), the Netherlands (Dijkgraaf and Gradus, 2003), Spain (Bel and Fageda, 2010), Sweden (Ohlsson, 2003), and the United Kingdom (Szymanski and Wilkins, 1993; Szymanski, 1996)).

Several influential factors examined in this study have also been individually considered in the literature. For instance, the economy-of-scale aspect has been examined in Dubin and Navarro (1988), Szymanski and Wilkins (1993), Szymanski (1996), Bel and Fageda (2010) and Greco et al. (2015), and these studies revealed increasing returns to scale (IRS) in MSW management production schemes. Collins and Downes (1977), Callan and Thomas (2001), Reeves and Barrow (2000) and Dijkgraaf and Gradus (2003) found constant returns to scale (CRS) while Domberger et al. (1986) and Bosch et al. (2000) found decreasing returns to scale (DRS).

In addition, in regards to market-structure factors, Tickner and McDavid (1986) found that the costs of MSW management decrease when municipalities contract out their services to a private waste management company. Moreover, the impact of compulsory competitive tendering on the costs of MSW management in the UK was estimated by Domberger et al. (1986). The authors found no difference in public and private costs under competitive contracting but that public costs become higher than private costs in the absence of competition. Zhu et al. (2016) evaluated the performance of a hypothetical public-private partnership for the city of Hamilton (Ontario, Canada) in comparison with public and private collection systems and reached the conclusion that the mixed-management option could serve as a reasonable solution.

Estimations of recycling costs have also been attempted by Kinnaman et al. (2014) who assumed that the social cost of recycling can be expressed as the sum of municipal costs and revenues, recycling costs to households, external disposal costs, and external recycling benefits. The authors estimated an optimum recycling rate, i.e., the rate that minimizes social costs, of roughly 10% for Japan and concluded that the value of citizen engagement in recycling programs is actually overestimated. Callan and Thomas (2001) and Weng and Fujiwara (2011) estimated the role of waste and recycling cost functions and came to the exact opposite conclusion that recycling leads to the reduction of total waste management costs. Massarutto et al. (2011) performed an economic life-cycle analysis to compare the costs of alternative waste management scenarios in north-central Italy. According to the authors' findings, the financial costs of waste management increase when waste separation at the household level increases beyond 60% and by only 30% for some municipalities. Greco et al. (2015) also examined the impacts of source separation on the costs of a complete MSW management system. They found that the overall percentage of recycled waste is positively related to paper, paperboard, and organic collection costs.

While these papers have examined MSW management from various angles, we believe that the literature still presents several limitations first with respect to geographical breadth, as studies conducted outside of North America and Europe remain very limited. One study by Ren and Hu (2014) analyzed the financial performance of MSW services in China and found that labor accounts for more than half to up to three-quarters of the opera-

Please cite this article in press as: Chifari, R., et al. Does recyclable separation reduce the cost of municipal waste management in Japan?. Waste Management (2017), http://dx.doi.org/10.1016/j.wasman.2017.01.015