Chapter 4

Cost Efficiency of Regional Waste Management and Contracting Out to Private Companies

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Abstract

The chapter examines cost efficiency of regional waste management (RWM) and contracting out to private companies, considering each stage of waste management: collection, intermediate, and final disposal. First, it presents existing studies on this subject to evaluate the evidence and controversial issues. Then, the study uses a Japanese cross-sectional dataset to estimate the average costs for each stage of waste management, focusing on RWM and contracting out to private companies. Finally, the chapter discusses possible RWM in Southeast Asia, based on a simple empirical analysis using a dataset from the Philippines.

Keywords: regional waste management, economies of scale, contracting out to private companies, cost efficiency

4.1. Introduction

The proper treatment of generated waste is necessary, particularly in developing countries. However, solid waste management imposes a heavy burden on municipal finances. According to Kaza, et al. (2018), this line item alone comprises nearly 20% of low-income countries' municipal budgets. This means that cost efficiency in waste management is an extremely important issue.

Regional waste management (RWM) and contracting out to private companies are expected to contribute to a more efficient management of municipal solid waste (MSW). As further explained in section 4.2, most studies in the current literature were conducted

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in developed countries and focus on waste collection costs by examining the total cost of waste management.[19] Actually, RWM increases not only the amount of waste disposed but also expands the collection area. Therefore, RWM may not actually contribute to its cost reduction, because simple economies of scale do not apply. This suggests that it is important to examine not only the collection and transport of MSW but also its disposal costs in order to analyse RWM's cost efficiency.

However, there are still controversial issues regarding RWM's economies of scale and the cost efficiency of contracting out to private companies, as shown in section 4.2. Therefore, this chapter aims to clarify which condition will best attain cost savings in waste management, considering each of its three stages: collection, intermediate disposal, and final disposal.

This chapter proceeds as follows. Section 4.2 reviews the existing literature regarding this issue, including a presentation of the related evidence and controversial issues. Section 4.3 conducts a simple econometric analysis to estimate the determinants of waste management costs, using a Japanese cross-sectional dataset. Section 4.4 discusses the possibility of RWM in Southeast Asia, after conducting a straightforward econometric analysis using a Philippine cross-sectional dataset. Finally, Section 4.5 offers concluding remarks.

4.2. Literature on Cost Analyses of Regional Waste Management and Contracting Out to Private Companies

4.2.1. Economies of Scale in Waste Management

Many studies have examined waste management costs using econometric methods. Most have focused on the cost of waste collection by examining the total cost of waste management. Here our first research question is presented—do economies of scale exist in waste management or not?

There are supposed to be two types of economies of scale in the general sense (Bel and Warner, 2015; Callan and Thomas, 2001; Sasao, 2019). One type is economies of density and the other type is economies of scale. The former represents the percentage increase in costs for every 1% increase in population or household density. If it is less than one, economies of density exist. The latter represents the percentage increase in costs for every 1% increase in the amount of waste. If it is less than one, economies of scale exist. For economies of density and scale, several studies confirmed that economies of density

[19] This seems to be due to lack of available data.

exist in waste collection, while other studies indicated that they were not found.

Stevens (1978) used a cross-sectional dataset for 340 United States (US) cities during the 1974–1975 period to examine collection costs in waste management. He indicated that economies of scale were observed up to a population of approximately 20,000 inhabitants. Dubin and Navarro (1988) also used a cross-sectional dataset for 261 US cities during the 1974–1975 period in order to examine collection costs. They demonstrated that economies of household density were observed. Carroll (1995) used a cross-sectional dataset of 57 Wisconsin, US cities with kerbside recycling programmes in 1992 to estimate recycling costs. He indicated that economies of household density were observed, although they were not observed for recycling. Callan and Thomas (2001) used a cross-sectional dataset for 110 Massachusetts, US cities and towns during the 1997–1998 period to separately estimate disposal costs (other than recycling) and recycling costs. They also indicated that economies of household density were observed, although economies of scale were not observed for disposal types other than recycling. In contrast, they indicated that for recycling, economies of scale were, in fact, observed even though economies of density were not. On the other hand, they suggested that there were economies of scope and that joint provision of disposal and recycling services is more efficient than providing either one by itself.[20]

Ohlsson (2003) analysed a cross-sectional dataset of 430 municipalities in Norway to examine the effect of inter-municipal cooperation (IMC). He suggested that while IMC would increase overall waste collection cost per inhabitant, the increase in the population being served would contribute to establishing economies of scale for each individual municipality. He also indicated that an increase in ownership concentration would reduce user fees and costs. Usui (2007) used a panel dataset for 2,592 municipalities and inter-municipalities in Japan from 1998 to 2002 to estimate the total cost of MSW management. He showed that economies of scale were observed more remarkably in individual municipalities with 50,000 residents or less, although in some cases they were also observed in municipalities with over 50,000 inhabitants. In addition, Usui (2007) indicated that IMC for the final disposal stage would contribute to cost savings, although employing IMC for the intermediate disposal stage might increase management costs. Lombrano (2009) collected a cross-sectional dataset for Italian regions for the years of 2002 through 2004 in order to analyse the relationship between the average cost of collection and transport with population and waste management type. He indicated that a negative

[20] Economies of scope exist if the cost of one municipality providing both disposal and recycling is lower than if each of the two municipalities specialised in only one of these services for the residents of respective municipalities (Callan and Thomas, 2001).

relationship existed between average cost and population.

Bel and Warner (2015) surveyed the literature on cost savings under IMC and established that varied results might be caused by differences in the average populations of municipalities and the governance of cooperative arrangements amongst countries. Actually, several studies provided significant insights regarding the conditions under which economies of scale could and could not be observed. Dijkgraaf and Gradus (2005) used a cross-sectional dataset of 453 municipalities in the Netherlands in 2002 to estimate waste collection costs. They showed that there was no significant difference in cost between collection by an inter-municipality and by a municipality itself. Bel and Costas (2006) used a cross-sectional dataset of 186 municipalities in Catalonia, Spain in 2000 to estimate the total cost of waste management, including collection, transport, disposal, and elimination. They demonstrated that although economies of scale were observed for municipalities below 10,000 residents, they were not observed in municipalities with populations of 20,000 or more. In contrast, population density did not significantly affect total costs, that is, economies of density were not observed. Bel and Mur (2009) collected a cross-sectional dataset for 56 municipalities that featured over 1,000 inhabitants in Aragon, Spain in 2003 in order to calculate waste management costs. They indicated that IMC reduced costs in municipalities with populations below 10,000 inhabitants. In contrast, there was no significant relationship between population density and cost. Bel and Fageda (2010) collected a cross-sectional dataset for 65 municipalities in Galicia, Spain in 2005 to analyse MSW service costs. They showed that economies of scale specifically existed in waste collection costs for municipalities with less than 50,000 inhabitants. Consequently, they suggested that cooperation between small municipalities could promote cost savings. Bohm, et al. (2010) used a cross-sectional dataset for 1,021 municipalities in the US in 1997 to estimate cost functions for waste collection and disposal services and kerbside recycling programmes. They demonstrated that economies of scale were present in both types of waste management. However, they indicated that the average total cost of recycling was minimised at the rate of 13,200 tons of material recycling per year, which corresponds to approximately 80,000 inhabitants.

Yamamoto (2009) used a cross-sectional dataset for 1,844 Japanese municipalities in 2005 to estimate waste collection and disposal costs. He established that no economies of scale in waste collection were observed in large municipalities (for which the collected amount was more than 45,000 tons per year), although they were observed in the average costs of waste collection and disposal. He further suggested that economies of household density in waste collection existed. Greco, et al. (2015) collected a cross-sectional dataset for 67 Italian municipalities in 2011 to analyse collection costs for each type of waste. They indicated that economies of scale could be observed particularly in the waste collection of undifferentiated waste. They also suggested that economies of density existed for heavy multi-material waste (glass, plastic, and metal). Chifari, et al. (2017) employed a cross-sectional dataset of 1,724 Japanese municipalities in 2010 to estimate cost elasticities of the three waste treatment stages (collection, intermediate disposal, and final disposal). They showed that collection costs were less elastic than were disposal costs, despite the fact that economies of scale were observed in all three of the treatment stages. Soukopová, Vaceková, and Klimovský (2017) collected a cross-sectional dataset of 2,065 municipalities in the Czech Republic to analyse different forms of local waste collection services. They discovered that IMC promoted cost savings, particularly in smaller municipalities that featured populations consisting of less than 500 inhabitants. Ishimura and Takeuchi (2018) used a pooled panel dataset for all Japanese municipalities for the years 2006 to 2015 in order to estimate the total cost of waste management. They demonstrated that IMC promoted cost savings on average and that higher savings were found in smaller municipalities. They also observed economies of scope, that is, IMC in recycling and landfilling, as well as incineration, contributed to cost reduction.

The main results of the above studies are summarised in Table 4.1.[21] Based on the existing literature, many study results suggest that economies of scale exist in waste management. However, most indicate that such economies of scale were observed particularly in smaller municipalities.

[21] As for economies of scale for waste disposal facilities, Matsuto and Ohara (2010) demonstrated that economies of scale for landfill sites (scale to the power of 0.5 or 0.6) in Japan existed, although they did not use any econometric methods. Sasao (2019) examined construction costs for 77 incinerators in Japan. He showed that economies of scale existed for incinerators with less than 428 tons per day capacity.

Table 4.1. Literature of Economies of Scale and Contracting out to Private Companies in Waste Management

	Economies of Density	Economies of Scale	Contracting out to Private Companies
Collection	[Observed] Dubin and Navarro (1988) Carroll (1995) Yamamoto (2009) [Not observed] Greco et al. (2015)	[Observed] Stevens (1978) Lombrano (2009) Yamamoto (2009) (<45000 tons) Bel and Fageda (2010) Bohm et al. (2011) Zafra-Gómez et al. (2013) Greco, et al. (2015) Soukopova, Vaceková, and Klimovský (2017) [Not observed] Carroll (1995) Antonioli and Filippini (2002) Dijkgraaf and Gradus (2005) Yamamoto (2009) (>45000 tons)	[Observed] Dijkgraaf and Gradus (2005)[*1] Yamamoto (2009) [*2] Soukopova Vaceková, and Klimovský (2017) (big cities) [Not observed] Dubin and Navarro (1988)[*3] Ohlsson (2003)[*4] Bel and Fageda (2010)[*1] Zafra-Gómez, et al. (2013)[*4] Greco, et al. (2015) [*4,5] Ishimura and Takeuchi (2017)
Collection and disposal	[Observed] Callan and Thomas (2001) Ishimura and Takeuchi (2017) [Not observed] Bel and Mur (2009)	[Observed] Bel and Costa (2006) Usui (2007) Bel and Mur (2009) Chifari, et al. (2017) Ishimura and Takeuchi (2017) [Not observed] Callan and Thomas (2001)	[Observed] Usui (2007) [Not observed] Bel and Costas (2006) Bel and Mur (2009)

PPP = public–private partnership.
Note: [*1] PPP increases cost.
[*2] Except for only one private company.
[*3] Private organisation is more expensive than contract organisation.
[*4] Public is cheaper.
[*5] Privatisation is cheaper for organic waste collection.
Source: Compiled by the author.

4.2.2. Privatisation and Contracting Out to Private Companies of Waste Management

This chapter's second research question is – does the privatisation or contracting out to private companies of waste management contribute to cost savings? Regarding this question, several studies indicate that the privatisation or the contracting out to private companies of waste collection did promote cost savings, while other studies indicated that doing so did not, in fact, reduce costs.

Stevens (1978) demonstrated the fact that a private monopolist proved to be more efficient than a public monopolist. Carroll (1995) also showed that the municipal collection of waste was more expensive than private collection. Dijkgraaf and Gradus (2005) indicated that waste collection by public firms was as cost efficient as private collection, although private collection was cheaper than collection by municipalities. They suggested that maintaining a sufficient level of competition was rather important for promoting cost reduction in this industry. Usui (2007) indicated that public collection was more expensive than contracting out to private companies. Yamamoto (2009) also indicated that contracting out to one monopolistic company increased collection costs, although contracting out to private companies promoted a reduction in costs. In addition, Chifari, et al. (2017) indicated that private companies, through public tender and the coordination of adjacent municipalities, or IMC, led to cost reductions. Soukopová, Vaceková, and Klimovský (2017) showed that contracting out promoted cost savings regardless of population size, although public–private partnerships (PPPs) increased collection costs in small municipalities.[22]

In contrast, Dubin and Navarro (1988) demonstrated that waste collection by private organisations was more expensive than collection by contracted organisations. Bel and Costas (2006) and Bel and Mur (2009) also indicated that there was no significant difference in the costs observed of private and public waste management services. In addition, Lombrano (2009) suggested that no correlation was found between privatisation and cost efficiency. Bel and Fageda (2010) also established that private collection was not necessarily cheaper than public service. Zafra-Gómez, et al. (2013) used a panel dataset to evaluate the efficiency of waste collection services in 923 Spanish local authorities with populations of less than 50,000 inhabitants. They showed that although private management did not promote cost savings for small and medium-sized local

[22] Sasao (2019) also showed that the adoption of the Private Finance Initiative (PFI) raised construction costs contrary to a priori expectations. He noted that 'in case of PFI, private companies tend to execute a bulk contract to build incinerators, including their operation, with municipalities. Some companies set off the operation costs against the higher construction costs while they manage to operate at lower prices' (Sasao, 2019, pp.10–11). In addition, a government subsidy for siting incinerators might increase construction costs.

authorities, inter-municipal public management did, in fact, achieve cost savings. Greco, et al. (2015) also showed that no significant difference between private and public services were observed, except in the case of organic waste collection.

The main findings of the above studies are also summarised in Table 4.1. Based on the existing literature, it is still considered a controversial issue if privatisation, or contracting out to private companies, contributes to cost savings or not. It should be noted that sufficient competition plays a key role in the promotion of cost savings, as some studies have pointed out.

4.3. Econometric Analysis of RWM's Cost Efficiency and Contracting Out to Private Companies

4.3.1. Data and Methodology

This section conducts a simple econometric analysis using ordinary least squares (OLS) regression to clarify differences in waste management costs between municipalities and inter-municipalities and its determinants, taking each stage of waste management (collection, intermediate disposal, and final disposal), into consideration. The study uses a cross-sectional dataset for all municipalities and inter-municipalities conducting each stage of waste management in Japan in 2017, which are available from the Expenses of Municipal Waste Management and the Outline of Municipal Waste Management by the Ministry of the Environment in Japan (MOE).[23] The total observations during the data collection stage were 1,594 (1,459 municipalities and 135 inter-municipalities).[24] The total observations for the intermediate disposal stage were 1,474 (1,080 municipalities and 394 inter-municipalities). The total observations for the final disposal stage were 1,245 (942 municipalities and 303 inter-municipalities).

First, the study estimates the average cost of waste management, based on the pooled data for all municipalities and inter-municipalities. Second, it estimates costs, based on grouped data that separates municipalities that independently conduct waste management from inter-municipalities. The details of each model are provided in the following sub-section.

[23] Both are available from the website of the MOE, http://www.env.go.jp/recycle/waste_tech/ippan/h29/index.html, in Japanese.

[24] One municipality, Iidate village, is removed because most inhabitants are still evacuated out of the village due to radioactive contamination from the Fukushima Daiichi nuclear power station disaster.

Pooled Models

The dependent variables are the two types of average costs: cost per ton and cost per capita. The independent variables are divided into four categories: demographic determinants and amount of waste (in tons), whether municipalities conduct waste management independently or have IMC agreements, service level and waste management technology, and geographic determinants.

For demographic determinants and waste amounts, registered population or total amount of treated waste, rate of foreigners (ratio of registered foreigners to total population), and waste amount per day per capita are considered. An increase in population and total amount of treated waste is expected to reduce both average cost per ton as well as cost per capita due to economies of scale. An increase in the rate of foreigners may raise average costs because of an increase in non-separated waste if foreigners are unfamiliar with Japanese-style waste separation. An increase in waste amount per day per capita can reduce the average cost per ton if economies of scale exist. In contrast, an increase in waste amount per capita is also likely to raise the average cost per capita proportionally. The variables for registered population, total amount of treated waste, and waste amount per capita are log transformed to capture elasticity in the estimations.

The independent variables are selected considering differences in the dependent variables and the various stages of waste management. For service level and technology, the study considers the collection frequency of burnable, plastic packaging, and organic waste; the recycling rate; and items of separated waste. An increase in the collection frequency of burnable, plastic packaging, and organic waste can raise the average collection costs as well as intermediate disposal costs due an increase in these types of waste. In contrast, an increase in the collection frequency of burnable waste and plastic packaging waste can reduce the average cost of final disposal due to reducing the residue brought into landfill sites, although an increase in collection frequency of burnable waste can increase final disposal costs. The recycling rate, excluding ash recycling after incineration, is considered at the collection stage, and when it is included is considered at the intermediate and final disposal stages. An increase in the recycling rate and items of separated waste can raise both average collection and intermediate disposal costs, while it may reduce those of final disposal. In addition, for the collection sector, the rate of outsourced management to private companies for household waste is considered. In the intermediate disposal stage, the study calculates the rate of directly incinerated waste and the rate of residue after incineration and after treatment. An increase in these rates can raise the average cost of intermediate disposal. In the final disposal stage, the rate of direct landfilled waste and the rate of residue after incineration and after treatment are considered. An increase in these rates can increase the average cost of the final disposal stage.

Whether municipalities conduct waste management independently or share waste management through inter-municipality agreements is considered a dummy variable that equals one if there is inter-municipal waste management organisation and zero if there is not. Inter-municipal organisation is expected to promote cost savings if economies of scale exist.

Regarding geographic determinants, the area, if it is an isolated island or not, and whether municipalities include isolated islands or not are considered as dummy variables. An expansion in the area can increase the average cost of collection, although it is difficult to expect the possible effects on intermediate and final disposal *a priori*. The area is log transformed to capture elasticity in the estimation. The variable for isolated islands, represented by 'Islands,' is a dummy variable that equals one when the whole municipality is located on an isolated island and zero when it is not. The variable for municipalities that include isolated islands, represented by 'Municipalities including islands,' is a dummy variable that equals one when a municipality or inter-municipality contains isolated islands and zero when it does not. Waste collection costs are supposed to be higher in the municipalities and inter-municipalities that feature isolated islands due to the necessity of transporting waste on ships, for example. On the other hand, it is unknown what the cost effects of this variable are on the intermediate and final disposal stages.

Tables 4.2, 4.3, and 4.4 tabulate the descriptive statistics of the variables considered in the analysis and the *a priori* expectations for effect of the independent variables on the dependent variables (average cost per ton and per capita). The correlation coefficients indicate that the relationship between the independent variables is negligible.

Table 4.2. Descriptive Statistics of Municipalities and Inter-Municipalities for Waste Collection in Japan

Variables	Mean	Median	SD	Max	Min	*a priori* effect
Average costs per ton (¥)	16,851	14,011	15,998	439,820	1	
Average costs per capita (¥)	4,531	3,813	4,775	144,678	0	
Population (person)	81,679	31,437	193,728	3,738,759	152	–
Rate of foreigners (%)	1.2	0.8	1.3	19.6	0.0	+?
Total amount of treated waste (tons)	23,541.3	8,683.0	56,791.8	950,301.0	50.0	–
Waste amount per day per capita (grams)	909.8	884.7	260.4	4,436.3	297.9	–/+
Dummy of inter-municipalities	0.1	0.0	0.3	1.0	0.0	–
Recycling rate (excluding recycling after treatment) (%)	18.7	17.3	9.0	82.0	0.6	+
Collection frequency of burnable waste (times per week)	2.0	2.0	0.6	5.0	0.0	+
Collection frequency of plastic waste (times per week)	1.9	2.0	1.7	5.0	0.0	+
Collection frequency of organic waste (times per week)	0.8	0.0	2.1	7.0	0.0	+
Items of separated waste	13.7	14.0	5.1	38.0	2.0	+
Rate of outsourced collection (%)	84.1	99.9	30.7	100.0	0.0	–
Area (km^2)	257.2	139.0	319.1	2,762.7	3.5	+
Dummy of islands	0.04	0.00	0.18	1.00	0.00	+
Dummy of municipalities including islands	0.06	0.00	0.24	1.00	0.00	+

km^2 = square kilometres, SD = standard deviation.
Source: Author's calculation.

Table 4.3. Descriptive Statistics of Municipalities and Inter-Municipalities for Intermediate Disposal in Japan

Variables	Mean	Median	SD	Max	Min	*a priori* effect
Average costs per ton (¥)	15,533	11,500	23,367	54,783	0	
Average costs per capita (¥)	5,224	3,939	7,795	14,051	0	
Population (person)	119,214	48,240	333,233	9,384,987	310	–
Rate of foreigners (%)	1.3	0.9	1.3	19.6	0.0	+
Total amount of treated waste (tons)	40,114.6	16,065.5	115,082.4	3,270,934.0	67.0	–
Waste amount per day per capita (grams)	913.1	890.3	261.0	4,436.3	67.7	–/+
Dummy of inter-municipalities	0.267	0.000	0.443	1.000	0.000	–
Recycling rate (including recycling after treatment) (%)	22.0	19.1	12.9	99.7	0.0	+
Rate of directly incinerated waste (%)	73.6	80.8	21.7	99.4	0.0	+
Rate of residue after incineration (%)	6.3	6.8	4.9	74.2	0.0	+
Rate of residue after treatment (%)	1.6	0.8	3.5	67.6	0.0	+
Collection frequency of burnable waste (times per week)	2.0	2.0	0.6	5.0	0.0	+
Collection frequency of plastic waste (times per week)	2.0	2.0	1.7	5.0	0.0	+
Collection frequency of organic waste (times per week)	0.8	0.0	2.1	7.0	0.0	+
Items of separated waste	14.2	14.0	5.1	45.0	2.0	+
Dummy of islands	0.03	0.00	0.17	1.00	0.00	+
Dummy of municipalities including islands	0.07	0.00	0.26	1.00	0.00	+

SD = standard deviation.
Source: Author's calculation.

Table 4.4. Descriptive Statistics of Municipalities and Inter-Municipalities for Final Disposal in Japan

Variables	Mean	Median	SD	Max	Min	*a priori* effect
Average costs per ton (¥)	3,451	1,573	6,365	62,597	1.0	
Average costs per capita (¥)	1,166	515	2,172	22,863	0	
Population (person)	121,900	47,046	366,520	9,384,987	310.0	–
Rate of foreigners (%)	1.3	0.9	1.3	19.6	0.0	+
Total amount of treated waste (tons)	40,939	15,247	123,916	3,270,934.0	67.0	–
Waste amount per day per capita (grams)	921.4	900.1	254.8	4,436.3	297.9	–/+
Dummy of inter-municipalities	0.243	0.000	0.429	1.000	0.000	–
Recycling rate (including recycling after treatment) (%)	21.4	18.9	12.4	99.7	0.0	–
Rate of directly landfilled waste (%)	0.0	0.0	0.1	0.9	0.0	+
Rate of residue after incineration (%)	0.1	0.1	0.0	0.7	0.0	+
Rate of residue after treatment (%)	0.0	0.0	0.0	0.7	0.0	+
Collection frequency of burnable waste (times per week)	2.0	2.0	0.6	5.0	0.0	+
Collection frequency of plastic waste (times per week)	2.0	2.0	1.7	5.0	0.0	–
Collection frequency of organic waste (times per week)	0.8	0.0	2.1	7.0	0.0	–
Items of separated waste	14.0	14.0	5.1	45.0	2.0	–
Dummy of islands	0.035	0.000	0.185	1.000	0.000	+
Dummy of municipalities including islands	0.075	0.000	0.264	1.000	0.000	+

SD = standard deviation.
Source: Author's calculation.

Grouped Models

The dependent variables are the two types of average cost – cost per ton and cost per capita. The independent variables are divided into the same four categories as with the pooled models. For the grouped models, the number of constitutional municipalities rather than the dummy variable for inter-municipalities is considered for inter-municipalities. An increase in the number of constituent municipalities can increase management costs because of the increasing administrative costs due to the combination of additional municipalities into inter-municipality groups. The other independent variables are similar to those used in the pooled models.

Tables 4.5,4.6, and 4.7 show the descriptive statistics of the variables for each group: municipalities that conduct waste management independently and those that have inter-municipality agreements. The tables show that both average cost per ton and per capita for inter-municipalities are cheaper than those for municipalities that independently conduct waste management for the collection and final disposal stages, while they are more expensive for the intermediate disposal stage. This phenomenon will be discussed in section 4.3.2 with the discussion on the estimation results. The correlation coefficients indicate that the relationships between dependent variables are negligible for both groups.

Table 4.5. Descriptive Statistics of Municipalities and Inter-Municipalities for Collection in Japan

Variables	Municipalities					Inter-Municipalities				
	Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min
Average costs per ton (¥)	17,697	14,480	16,267	439,820	7	7,707	5,945	8,454	37,383	1
Average costs per capita (¥)	4,775	3,994	4,881	144,678	2	1,899	1,312	2,065	11,558	0
Population (person)	77,835	28,608	197,971	3,738,759	152	123,218	83,545	133,528	713,797	1,473
Rate of foreigners (%)	1.2	0.9	1.3	19.6	0.0	1.2	0.8	1.3	10.6	0.2
Total amount of treated waste (tons)	22,474.4	8,025.0	57,922.5	950,301.0	50.0	35,071.9	24,379.0	41,131.3	215,794.0	491.0
Waste amount per day per capita (grams)	913.9	888.4	267.6	4,436.3	297.9	865.7	865.9	156.3	1,316.6	370.1
Number of constituent municipalities						3.3	3.0	1.6	10.0	2.0
Recycling rate (including ash recycling) (%)	21.6	18.8	13.2	99.7	0.6	21.2	18.2	12.3	78.5	4.3
Recycling rate (excluding ash recycling) (%)	18.8	17.4	9.2	82.0	0.6	17.6	17.2	7.0	39.2	4.3
Collection frequency of burnable waste (times per week)	2.0	2.0	0.6	5.0	0.0	2.0	2.0	0.4	3.0	0.0
Collection frequency of plastic waste (times per week)	1.9	2.0	1.8	5.0	0.0	1.8	2.0	1.4	4.3	0.0
Collection frequency of organic waste (times per week)	0.8	0.0	2.1	7.0	0.0	0.6	0.0	1.7	7.0	0.0
Number of separated waste	13.8	14.0	5.1	38.0	2.0	12.8	12.8	4.4	30.0	4.4
Rate of outsourced	83.9	100.0	31.2	100.0	0.0	85.4	98.7	24.7	100.0	0.0

collection (%)										
Area (km^2)	221.2	125.6	255.6	2,177.6	3.5	647.7	492.6	575.2	2,762.7	14.7
Dummy of islands	0.04	0.00	0.19	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Dummy of municipalities including islands	0.07	0.00	0.25	1.00	0.00	0.02	0.00	0.15	1.00	0.00

km^2 = square kilometres, SD = standard deviation.
Source: Author’s calculation.

Table 4.6. Descriptive Statistics of Municipalities and Inter-Municipalities for Intermediate Disposal in Japan

Variables	Municipalities					Inter-Municipalities				
	Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min
Average costs per ton (¥)	14,978	10,504	20,869	358,425	2	17,056	13,989	29,114	547,831	5
Average costs per capita (¥)	5,130	3,565	7,800	127,365	1	5,480	4,591	7,787	140,508	1
Population (person)	94,726	35,564	226,498	3,738,759	310	186,336	107,635	518,834	9,384,987	1,473
Rate of foreigners (%)	1.3	0.9	1.3	19.6	0.0	1.3	0.8	1.2	10.6	0.1
Total amount of treated waste (tons)	31,937.3	11,813.5	76,492.4	1,154,890.0	67.0	62,529	34,406	181,350	3,270,934.0	528.0
Waste amount per day per capita (grams)	922.9	894.9	289.7	4,436.3	67.7	886.2	878.9	154.8	1,893.5	370.1
Number of constituent municipalities						3.5	3.0	2.2	23.0	2.0
Recycling rate (including ash recycling) (%)	22.4	19.5	13.3	99.7	0.0	20.9	18.7	11.6	95.8	2.3
Rate of directly incinerated waste (%)	0.7	0.8	0.2	99.4	0.0	0.8	0.8	0.2	93.9	0.0
Rate of residuals after incineration (%)	0.1	0.1	0.1	74.2	0.0	0.1	0.1	0.0	46.6	0.0
Rate of residuals after treatment (%)	0.0	0.0	0.0	67.6	0.0	0.0	0.0	0.0	48.4	0.0
Collection frequency of burnable waste (times per week)	2.0	2.0	0.6	5.0	0.0	2.0	2.0	0.4	3.5	0.0
Collection frequency of plastic waste (times per week)	2.0	2.0	1.7	5.0	0.0	1.8	2.0	1.4	4.7	0.0
Collection frequency of	0.9	0.0	2.2	7.0	0.0	0.7	0.0	1.5	7.0	0.0

organic waste (times per week)										
Items of separated waste	14.4	14.0	5.3	45.0	2.0	13.7	13.3	4.3	30.0	4.3
Dummy of islands	0.04	0.00	0.19	1.00	0.00	0.01	0.00	0.11	1.00	0.00
Dummy of municipalities including islands	0.07	0.00	0.26	1.00	0.00	0.07	0.00	0.26	1.00	0.00

SD = standard deviation.
Source: Author's calculation.

Table 4.7. Descriptive Statistics of Municipalities and Inter-Municipalities for Final Disposal in Japan

Variables	Municipalities					Inter-Municipalities				
	Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min
Average costs per ton (¥)	3,884	1,720	7,086	62,597	2	2,105	1,252	2,835	22,155	1
Average costs per capita (¥)	1,325	576	2,426	22,863	0	674	400	877	7,245	0
Population (person)	98,191	36,388	225,256	3,738,759	310	195,606	102,916	622,942	9,384,987	1,473
Rate of foreigners (%)	1.3	0.9	1.4	19.6	0.0	1.3	0.8	1.2	10.6	0.2
Total amount of treated waste (tons)	33,144.5	11,980.0	74,893.2	1,154,890.0	67.0	65,169.4	32,673.0	212,121.7	3,270,934.0	528.0
Waste amount per day per capita (grams)	932.4	907.8	276.9	4,436.3	297.9	887.3	879.4	163.9	1893.5	370.1
Number of constituent municipalities						3.7	3.0	2.7	26.0	2.0
Recycling rate (including ash recycling) (%)	21.8	19.3	12.5	99.7	0.0	20.2	17.9	11.8	95.8	2.3
Rate of directly landfilled waste (%)	3.6	0.0	10.8	92.2	0.0	1.9	0.0	6.4	58.5	0.0
Rate of residuals after incineration (%)	6.3	6.8	5.0	74.2	0.0	7.1	7.7	4.7	46.6	0.0
Rate of residuals after treatment (%)	1.7	0.7	3.9	67.6	0.0	1.8	1.1	3.4	48.4	0.0
Collection frequency of burnable waste (times per week)	2.0	2.0	0.6	5.0	0.0	2.0	2.0	0.4	3.0	0.0
Collection frequency of plastic waste (times per week)	2.0	2.0	1.8	5.0	0.0	1.8	2.0	1.4	4.7	0.0
Collection frequency of	0.9	0.0	2.3	7.0	0.0	0.7	0.0	1.5	7.0	0.0

organic waste (times per week)										
Items of separated waste	14.2	14.0	5.3	45.0	2.0	13.5	13.0	4.5	30.0	4.3
Dummy of islands	0.04	0.00	0.20	1.00	0.00	0.02	0.00	0.14	1.00	0.00
Dummy of municipalities including islands	0.08	0.00	0.27	1.00	0.00	0.06	0.00	0.23	1.00	0.00

SD = standard deviation.
Source: Author's calculation.

4.3.2. Results

Tables 4.8, 4.9, and 4.10 show the estimation results of the collection, intermediate disposal, and final disposal stages in the pooled models, respectively. The tables demonstrate the results in the case in which only significant independent variables at the 10% significance level are included. Models 1-1 and 1-2 regress the average cost per ton, and Models 2, 2-1, and 2-2 regress those per capita. The models that end with '1' represent the models considering the dummy variable Islands, and those that end with '2' represent the models considering the dummy variable Municipalities including islands. However, only the results for Model 2 are shown in Table 4.8 because both dummy variables were not statistically significant.

Table 4.8: Estimation Results of Average Costs of Waste Collection in Japan

Variables	Model 1-1	Model 1-2	Model 2
Population (log)	-0.145*** (0.0150)	-0.151*** (0.0145)	
Rate of foreigners			0.616* (0.343)
Total amount of treated waste (log)			-0.131*** (0.0140)
Waste amount per day per capita (log)	-0.424*** (0.109)	-0.415*** (0.108)	0.509*** (0.105)
Inter-municipalities (D)	-1.656*** (0.177)	-1.649*** (0.177)	-1.641*** (0.172)
Recycling rate (excluding ash recycling)	0.00709*** (0.00267)	0.00719*** (0.00268)	0.00603** (0.00261)
Collection frequency of burnable waste	-0.112*** (0.0354)	-0.106*** (0.0355)	-0.0935*** (0.0336)
Collection frequency of plastic waste	0.0467*** (0.0116)	0.0478*** (0.0117)	0.0425*** (0.0115)
Items of separated waste	-0.0115*** (0.00392)	-0.0122*** (0.00390)	-0.0120*** (0.00385)
Rate of outsourced collection	-0.186*** (0.0648)	-0.191*** (0.0647)	-0.164** (0.0642)
Area (log)	0.0375* (0.0193)	0.0348* (0.0193)	
Islands (D)	0.313*** (0.115)		
Municipalities including islands (D)		0.191** (0.0902)	
Constant	7.135*** (0.730)	7.146*** (0.730)	-0.647 (0.716)
Observations	1,594	1,594	1,594
AIC	4,213.00	4,214.57	4,166.77
R-squared	0.287	0.286	0.281

AIC = Akaike Information Criterion.
Notes: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses. (D) represents a dummy variable.
Source: Author's calculation.

Table 4.9: Estimation Results of Average Costs of Intermediate Disposal in Japan

Variables	Model 1-1	Model 1-2	Model 2-1	Model 2-2
Waste amount per day per capita (log)			1.075***	1.088***
			(0.207)	(0.206)
Inter-municipalities (D)	0.705***	0.661***	0.732***	0.690***
	(0.0851)	(0.0853)	(0.0852)	(0.0852)
Recycling rate (including ash recycling)	0.00761*		0.00813*	
	(0.00419)		(0.00428)	
Rate of directly incinerated waste	-0.689***	-1.074***	-0.665***	-1.070***
	(0.247)	(0.192)	(0.248)	(0.192)
Rate of residue after treatment	2.108**	1.703*	2.137**	1.706*
	(0.904)	(0.944)	(0.912)	(0.954)
Collection frequency of plastic waste	0.0600**	0.0590**	0.0613**	0.0605**
	(0.0279)	(0.0281)	(0.0280)	(0.0281)
Items of separated waste	-0.0246***	-0.0293***	-0.0242***	-0.0286***
	(0.00919)	(0.00920)	(0.00922)	(0.00926)
Islands (D)	1.722***		1.709***	
	(0.175)		(0.178)	
Municipalities including islands (D)		0.843***		0.832***
		(0.165)		(0.168)
Constant	2.196***	2.725***	-6.270***	-5.806***
	(0.281)	(0.203)	(1.487)	(1.427)
Observations	1,474	1,474	1,474	1,474
AIC	5,726.60	5,744.60	5,727.26	5,745.28
R-squared	0.083	0.071	0.109	0.097

AIC = Akaike Information Criterion.
Notes: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses. (D) represents a dummy variable.
Source: Author's calculation.

Table 4.10: Estimation Results of Average Costs of Final Disposal in Japan

Variables	Model 1-1	Model 1-2	Model 2-1	Model 2-2
Population (log)	-0.248***	-0.253***		
	(0.0317)	(0.0303)		
Total amount of treated waste (log)			-0.244***	-0.249***
			(0.0319)	(0.0304)
Waste amount per day per capita (log)			1.228***	1.208***
			(0.192)	(0.189)
Rate of directly landfilled waste	2.851***	2.848***	2.846***	2.855***
	(0.335)	(0.334)	(0.343)	(0.343)
Rate of residue after incineration	3.021***	3.034***	3.057***	3.082***
	(0.856)	(0.849)	(0.851)	(0.844)
Rate of residue after treatment	3.247***	3.244***	3.266***	3.266***
	(0.910)	(0.908)	(0.910)	(0.907)
Collection frequency of plastic waste	0.105***	0.109***	0.104***	0.108***
	(0.0256)	(0.0257)	(0.0257)	(0.0258)
Items of separated waste	-0.0168**	-0.0172**	-0.0170**	-0.0174**
	(0.00848)	(0.00830)	(0.00851)	(0.00835)

Islands (D)	0.346**		0.352**	
	(0.171)		(0.178)	
Municipalities including islands (D)		0.354***		0.359***
		(0.115)		(0.119)
Constant	2.600***	2.633***	-5.799***	-7.015***
	(0.369)	(0.352)	(1.183)	(1.254)
Observations	1,245	1,245	1,245	1,245
AIC	4,488.30	4,485.50	4,487.41	4,484.60
R-squared	0.147	0.149	0.168	0.173

AIC = Akaike Information Criterion.
Notes: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses. (D) represents a dummy variable.
Source: Author's calculation.

In the collection stage, population is negatively significant on the average cost per ton in Models 1-1 and 1-2. A 1% increase in the population increases the average cost per ton by approximately 0.15%. The total amount of treated waste is also negatively significant on the average costs per capita by Model 2. A 1% increase in the total amount of treated waste increases the average cost per ton by approximately 0.13%. These results suggest that economies of scale in the collection stage do exist, similar to *a priori* expectations. The waste amount per capita decreases the average cost per ton significantly, although it increases the average cost per capita. Inter-municipality is negatively significant on both the average costs per ton and per capita. Considering that the variable is a dummy variable, inter-municipality waste management lowers the average cost per ton and per capita by 65–66% and 64%, respectively, compared with municipalities that conduct waste management independently. This suggests that IMC promotes the reduction of both the cost per ton and the cost per capita, similar to *a priori* expectations. On the other hand, the recycling rate and collection frequency of plastic waste are positively significant on both the average costs per ton and per capita. This indicates that the promotion of recycling increases the average cost of waste collection, similar to *a priori* expectations. In contrast, an increase in items of separated waste decreases the average cost of waste collection. Although this is contrary to our *a priori* expectation, it is likely that most municipalities collect recyclables efficiently despite having more items of separated waste to collect. For example, it is supposed that waste collectors pick up different recyclable types at the same time. The collection frequency of burnable waste is also negatively significant. This might be resulting from a reduction in the number of waste collection trips. In contrast, the collection frequency of plastic waste is positively significant. In addition, the increasing rate of outsourced collection to private companies is negatively significant for both the average cost per ton and per capita. A 1% increase in the rate of outsourced collection lowers average cost per ton and per capita by approximately 0.19% and 0.16%, respectively. This suggests that outsourcing during the collection stage specifically promotes the cost reduction, similar to *a priori* expectations. For the geographic determinants, the area is positively significant on the average costs per ton although it is not significant for the cost per capita. A 1% increase in the collection area raises the average cost per ton by approximately 0.03–0.04%. This indicates that increasing the area weakens the cost reductions attributable to IMC, though only slightly. Both dummy variables for isolated islands are positively significant on average cost per ton, though it is not significant for the cost per capita. Waste collection costs tend to be higher in the municipalities and inter-municipalities with isolated islands, similar to *a priori* expectations.

In the intermediate disposal stage, the waste amount per capita increases the average cost per capita significantly, although the population and total amount of treated waste do not affect the average cost per ton or per capita. A 1% increase in the waste amount per capita raises the average cost per capita by 1.1%, contrary to *a priori* expectations. Because the study focuses on management costs rather than construction costs, economies of scale seem not to be observed in the disposal stage. IMC is positively significant on both average cost per ton and per capita. Although this is contrary to *a priori* expectations, it is similar to the results obtained by Usui (2007). This phenomenon might be attributable to the fact that municipalities that originally had high costs tend to constitute IMC arrangements. IMC is supposed to establish cost savings due to promoting intensive disposal facilities. This should be observed in the siting of disposal facilities, such as incinerators, although it seems to be difficult to perform cost savings in the disposal management stage.[25] On the other hand, a higher rate of directly incinerated waste reduces both average cost per ton and per capita. It should be noted that intermediate disposal treatments include not only incineration but also compaction of bulky waste, composting, the creation of refuse-derived fuel, and recycling. Therefore, the phenomenon in which higher rates of directly incinerated waste reduce average costs might indicate that treatments other than incineration cause higher costs. Actually, a higher rate of recycling (including ash recycling) slightly increases the average cost per ton despite a 10% significance level, although it is not significant for the average cost per capita. A higher rate of residue after treatment increases both the average cost per ton and per capita despite a 10% significance level for the latter. This indicates that additional residue requires additional costs for further disposal. The collection frequency of plastic

[25] For example, Sasao (2019) suggested that economies of scale did exist for siting incinerators.

waste is positively significant on both the average cost per ton and per capita, although items of separated waste are negatively significant. This suggests that recycling plastics requires additional disposal costs, whilst waste separation at the source by households reduces disposal costs. For the geographic determinants, the dummy variables for isolated islands are positively significant for both the average cost per ton and per capita, and the impact of either a whole municipality or an inter-municipality being located on an isolated island are stronger than those of municipalities and inter-municipalities including islands.

In the final disposal stage, population is negatively significant on the average cost per ton in Models 1-1 and 1-2. The total amount of treated waste is also negatively significant on the average cost per capita in Models 2-1 and 2-2. These results suggest that economies of scale exist in the final disposal stage, similar to *a priori* expectations. In contrast, the waste amount per capita increases the average cost per capita. IMC is not significant for both the average cost per ton and per capita. On the other hand, a higher rate of directly landfilled waste and residue after incineration and treatment increase both the average cost per ton and per capita. This phenomenon indicates that more landfilled waste and residue require additional costs for final disposal, similar to *a priori* expectations. The collection frequency of plastic waste is positively significant on the average cost per ton and per capita, again, although items of separated waste are negatively significant on the average cost per ton and per capita. For the geographic determinants, in both cases – a whole municipality being located on an isolated island and a municipality or inter-municipality including isolated islands—are positively significant for both average cost per ton and per capita, and the impact is similar in the two cases. These are similar to *a priori* expectations.

Grouped Models

The estimation results for grouped models are shown in Tables 4.11, 4.12, and 4.13. These tables show the results for case of including only significant independent variables at the 10% significance level. Only the results of Models 1 and 2 are shown for inter-municipalities because both dummy variables for isolated islands were not significant. Notations for each model are the same as those in the pooled models.

Table 4.11. Estimation Results of Average Costs of Waste Collection in Japan

Variables	Municipalities				Inter-Municipalities	
	Model 1-1	Model 1-2	Model 2-1	Model 2-2	Model 1	Model 2
Population (log)	-0.0984***	-0.103***			-1.089***	
	(0.0126)	(0.0123)			(0.124)	
Rate of foreigners						
Total amount of treated waste (log)			-0.0796***	-0.0828***		-0.922***
			(0.0122)	(0.0119)		(0.112)
Waste amount per day per capita (log)	-0.365***	-0.341***	0.493***	0.490***		
	(0.0876)	(0.0870)	(0.0884)	(0.0881)		
Recycling rate (excluding ash recycling)	0.00917***	0.00934***	0.00828***	0.00849***		
	(0.00230)	(0.00234)	(0.00222)	(0.00223)		
Collection frequency of burnable waste	-0.0784**	-0.0816***	-0.0644**	-0.0609**		
	(0.0307)	(0.0311)	(0.0297)	(0.0301)		
Collection frequency of plastic waste	0.0299***	0.0316***	0.0258***	0.0270***	0.363***	0.299***
	(0.0100)	(0.0101)	(0.00989)	(0.00991)	(0.0983)	(0.0978)
Items of separated waste	-0.00958***	-0.00999***	-0.00961***	-0.00987***		
	(0.00325)	(0.00326)	(0.00324)	(0.00324)		
Rate of outsourced collection	-0.209***	-0.204***	-0.183***	-0.184***		
	(0.0570)	(0.0565)	(0.0567)	(0.0566)		
Area (log)	0.0286*					
	(0.0162)					
Islands (D)	0.365***		0.212**			
	(0.112)		(0.108)			
Municipalities including islands (D)		0.253***		0.196***		
		(0.0681)		(0.0663)		
Constant	6.221***	6.242***	-1.080*	-1.044*	12.45***	8.118***
	(0.572)	(0.582)	(0.585)	(0.587)	(1.356)	(1.050)

Observations	1,459	1,459	1,459	1,459	135	135
AIC	3,150.55	3,152.51	3,122.90	3,120.43	545.48	539.39
R-squared	0.108	0.105	0.079	0.081	0.303	0.283

AIC = Akaike Information Criterion.
Notes: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses. (D) represents a dummy variable.
Source: Author's calculation.

Table 4.12. Estimation Results of Average Costs of Intermediate Disposal in Japan

Variables	Municipalities				Inter-Municipalities	
	Model 1-1	Model 1-2	Model 2-1	Model 2-2	Model 1	Model 2
Population (log)					-0.501***	
					(0.0545)	
Rate of foreigners					8.182**	10.21**
					(3.853)	(4.332)
Total amount of treated waste (log)						-0.462***
						(0.0520)
Waste amount per day per capita (log)			1.205***	1.228***		0.944**
			(0.238)	(0.244)		(0.388)
Number of constituent municipalities					0.0754***	0.0700***
Recycling rate (including ash recycling)	0.0208***	0.0254***	0.0213***	0.0258***		-0.00881*
	(0.00382)	(0.00435)	(0.00391)	(0.00444)		(0.00518)
Rate of residue after incineration	2.157*	2.301*		2.260*		
	(1.176)	(1.202)		(1.196)		
Rate of residue after treatment	3.134***	3.320***	3.097***	3.276***		
	(1.017)	(1.010)	(1.038)	(1.034)		
Collection frequency of plastic waste	0.0914***	0.0901***	0.0927***	0.0916***		
	(0.0331)	(0.0330)	(0.0331)	(0.0330)		
Collection frequency of organic waste					0.0437*	0.0674**
					(0.0227)	(0.0262)
Items of separated waste	-0.0219**	-0.0257**	-0.0207*	-0.0243**		-0.0303*
	(0.0105)	(0.0104)	(0.0106)	(0.0105)		(0.0173)
Islands (D)	1.971***		1.863***			
	(0.195)		(0.203)			
Municipalities including islands (D)		1.249***		1.212***		
		(0.168)		(0.173)		

Constant	1.272***	1.059***	-8.064***	-8.433***	7.720***	-0.180
	(0.184)	(0.228)	(1.667)	(1.716)	(0.576)	(2.724)
Observations	1,080	1,080	1,080	1,080	394	394
AIC	4374.77	4380.87	4376.16	4382.10	1,184.46	1,179.67
R-squared	0.069	0.065	0.098	0.095	0.186	0.208

AIC = Akaike Information Criterion.
Notes: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses. (D) represents a dummy variable.
Source: Author’s calculation.

Table 4.13. Estimation Results of Average Costs of Final Disposal in Japan

Variables	Municipalities				Inter-Municipalities	
	Model 1-1	Model 1-2	Model 2-1	Model 2-2	Model 1	Model 2
Population (log)	-0.230***	-0.223***			-0.488***	
	(0.0336)	(0.0340)			(0.0717)	
Rate of foreigners					10.16**	11.33**
					(4.458)	(4.452)
Total amount of treated waste (log)			-0.234***	-0.226***		-0.457***
			(0.0340)	(0.0346)		(0.0730)
Waste amount per day per capita			1.439***	1.356***		0.952**
(log)			(0.217)	(0.223)		(0.406)
Number of constituent					0.0782**	0.0733**
municipalities					(0.0332)	(0.0331)
Recycling rate (including ash	0.00762*	0.00847*	0.00823*	0.00881**		
recycling)	(0.00439)	(0.00441)	(0.00448)	(0.00448)		
Rate of directly landfilled waste	3.063***	3.018***	2.972***	2.963***	1.779**	1.969***
	(0.370)	(0.362)	(0.382)	(0.374)	(0.719)	(0.742)
Rate of residue after incineration	3.805***	3.775***	3.771***	3.755***		
	(0.946)	(0.949)	(0.945)	(0.947)		
Rate of residue after treatment	3.852***	3.817***	3.800***	3.786***		
	(1.046)	(1.030)	(1.054)	(1.035)		
Collection frequency of plastic	0.107***	0.112***	0.110***	0.114***		
waste	(0.0292)	(0.0293)	(0.0294)	(0.0295)		
Items of separated waste	-0.0303***	-0.0281***	-0.0294***	-0.0276***	0.0237*	
	(0.00975)	(0.00976)	(0.00978)	(0.00979)	(0.0130)	
Municipalities including islands (D)		0.374***		0.355**		
		(0.134)		(0.140)		
Constant	2.376***	2.219***	-8.775***	-8.357***	4.867***	-3.239
	(0.409)	(0.423)	(1.471)	(1.484)	(0.829)	(2.871)

Observations	942	942	942	942	303	303
AIC	3471.02	3468.95	3472.14	3470.61	999.01	995.64
R-squared	0.150	0.154	0.180	0.183	0.149	0.150

AIC = Akaike Information Criterion.
Notes: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses. (D) represents a dummy variable.
Source: Author’s calculation.

In the collection stage, the results for municipalities that conduct waste management independently are similar to those in the pooled models. In contrast, for inter-municipality arrangements, the only significant variables are population in Model 1 and total amount of treated waste in Model 2. Population is negatively significant for the average cost per ton, and the total amount of treated waste is also negatively significant for the average cost per capita. A 1% increase in population reduces the average cost per ton by approximately 1.09%. A 1% increase in the total amount of treated waste reduces the average cost per capita by approximately 0.92%. These results, again, suggest that economies of scale do exist in the collection stage, and they are similar to *a priori* expectations. The collection frequency of plastic waste is positively significant for inter-municipalities similarly to municipalities that conduct waste management independently. No other significant variables were observed for inter-municipalities, whilst several other variables were significant for municipalities that conduct waste management independently, similar to cases using pooled models. This indicates that population and total amount of waste are important factors in the collection stage of RWM.

In the intermediate disposal stage, the results for municipalities that conduct waste management independently and inter-municipalities show different results. Population and the total amount of treated waste are negatively significant for inter-municipalities, although they are not significant for municipalities that conduct waste management independently. A 1% increase in population reduces the average cost per ton by approximately 0.5% for inter-municipalities. A 1% increase in the total amount of treated waste reduces the average cost per ton by approximately 0.46% for inter-municipalities. These results suggest economies of scale exist in the intermediate disposal stage only in inter-municipalities. The rate of foreigners is positively significant for inter-municipalities although it is not significant for municipalities that conduct waste management independently. Foreigners' lack of familiarity with Japanese waste separation in municipalities can raise the rate of unseparated waste, and consequently this may increase disposal costs at the intermediate disposal stage, similar to *a priori* expectations. However, the reason why this phenomenon is observed only in inter-municipalities is not clear. On the other hand, an increasing number of constituent municipalities increase disposal costs for inter-municipalities. A 1 increase in the number of constituent municipalities raises the average cost per ton or per capita by approximately 0.07% or 0.08%. This might result from an increase in administration costs due to the combining of more municipalities, although the impacts are slight, similar to *a priori* expectations. A higher rate of recycling (including ash recycling) slightly increases both the average cost per ton and per capita for municipalities that conduct waste management independently, although it is not significant for the average costs per ton and negatively significant for per capita despite a 10% significance level for inter-municipalities. The collection frequency of organic waste is positively significant for inter-municipalities, although it is not significant for municipalities that conduct waste management independently. Items of separated waste are negatively significant for average costs per capita despite a 10% significant level similarly to municipalities that conduct waste management independently. However, they are not significant for per ton for inter-municipalities. No other significant variables are observed for inter-municipalities, although they are observed for municipalities that conduct waste management independently, similar to pooled models.

In the final disposal stage, the results are somewhat different for municipalities that conduct waste management independently and inter-municipalities. Population and the total amount of treated waste are negatively significant in both municipalities that conduct waste management independently and inter-municipalities, similar to *a priori* expectations. A 1% increase in population reduces the average cost per ton by approximately 0.22–0.23% and 0.49% for the municipalities that conduct waste management independently and for the inter-municipalities, respectively. A 1% increase in the total amount of treated waste reduces the average cost per ton by approximately 0.23% and 0.46 % for municipalities that conduct waste management independently and inter-municipalities, respectively. The rate of foreigners is, again, positively significant for inter-municipalities, although it is not significant for municipalities that conduct waste management independently. An increasing number of constituent municipalities also increases disposal costs for inter-municipalities. A 1% increase in the number of constituent municipalities raises the average cost per ton and per capita by approximately 0.08% and 0.07%, respectively. The rate of directly landfilled waste is positively significant for both municipalities that conduct waste management independently and inter-municipalities. A 1% increase in the rate of directly landfilled waste increases the average cost per ton by approximately 3.8% and 1.8% for municipalities that conduct waste management independently and inter-municipalities, respectively. A 1% increase in the rate of directly landfilled waste increases the average cost per capita by approximately 3.0% and 2.0% for municipalities that conduct waste management independently and inter-municipalities, respectively. Items of separated waste are positively significant for average costs per ton despite a 10% significant level for inter-municipalities, although they are negatively significant for municipalities that conduct waste management independently. However, the reason for this is not clear.

4.4. Possible Applications for Developing Countries in Asia

As presented in Section 4.2, most existing cost analyses on waste management were conducted in developed countries. There are no empirical studies of waste management costs targeted at developing countries. Therefore, this section conducts a simple econometric analysis to clarify whether economies of scale are also observed in Asian developing countries or not. Here, we analyse MSW management costs in the Philippines as a case study. If economies of scale are also observed in the Philippines, RWM can be expected to contribute cost savings to waste management in other developing countries in Asia.

4.4.1. Data and Methodology

The study uses a dataset from the Survey of Solid Waste Management Cost in the Philippines prepared by Environweave Integrative Environmental Research (2019). The available number of municipalities for the study is 119 (including 22 cities) out of 1,634 municipalities. The study considers the total budget for MSW management with cost as a dependent variable. It should be noted that the total budget is not the average cost unlike the analysis in the previous section.[26] It considers population density (based on registered population), total amount of waste generation, rate of recyclables, number of *barangays* (the smallest unit of local government in the Philippines), and the number of materials recovery facilities (MRF) as the independent variables.[27] The cost, population density, and total amount of waste are transformed using logarithms in order to capture elasticity. If a 1% increase in population density raises costs by less than 1%, economies of density exist. A 1% increase in the amount of waste raises costs by less than 1%, economies of scale exist. The rate of recyclables represents the percentage of recyclables in the total amount of waste generated. An increase in the rate of recyclables can increase management costs due to increasing recyclables while it might decrease management costs due to material sales. An increase in the number of *barangays* might increase management costs because of the increasing administrative costs such as additional municipalities in inter-municipality groups. An MRF is a location or facility where MSW is separated or processed using mechanical and manual methods. MRFs are owned by *barangays* in general. An increase in the number of MRFs can increase management costs due to increasing

[26] Although the author also regressed the average cost instead of the total budgets, independent variables except for population density was not significant. Therefore, this section focuses on the total budget.
[27] Population density rather than population and area is considered in this case study unlike the analysis in the previous section because the study regresses the total cost rather than average cost. The total cost is assumed to be proportional to population and area.

recyclables while it might decrease management costs due material sales, similar to the rate of recyclables.

Table 4.14 tabulates descriptive statistics of the variables considered in the analysis. The correlation coefficients indicate that the relationships between the independent variables are negligible. Three combinations of different independent variables are regressed using the OLS method.

Table 4.14. Descriptive Statistics in the Philippines

Variables	Mean	Median	SD	Max	Min
Cost (total budget) (PHP)	35,900,000	3,312,000	85,200,000	606,000,000	3541.25
Average cost (PHP/ton)	1,720.32	923.54	2,856.81	21,622.86	0.3972603
Population density (person/km^2)	2,852.73	514.65	7,097.57	36,272.73	24.2915
Total amount of waste (tons)	24,505.27	5,489.34	56,308.69	361,606.60	134.685
Rate of recyclables	0.2187	0.2135	0.1151	0.5371	0.000318
Number of *barangay*	27.49	20	26.21	188	5
Number of MRF	9.11	0	25.98	142	0

km^2 = square kilometres, MRF = materials recovery facilities, SD = standard deviation.
Note: PHP100 (Philippine peso) = $2.13 (in 2015).
Source: Author's calculation.

4.4.2. Estimation Results

The estimation results of the three models are listed in Table 4.15. The results only include independent variables that are significant at the 5% significance level, which are shown in the column labelled Model 1. The results include only significant variables at the 10% significance level; the rate of recyclables and the number of MRF are shown in the columns labelled Model 2 and Model 3, respectively.[28] The model specification is the most suitable for Model 2 amongst the three models because the Akaike Information Criterion (AIC) is lowest in Model 2. Therefore, the following discussion is based on Model 2's results.

[28] In the case of including MRF rather than the rate of recyclables, MRF was not significant.

Table 4.15. Estimation Results of Waste Management Costs in the Philippines

Variables	Model 1	Model 2	Model 3
Population density (log)	0.335**	0.407**	0.404**
	(0.147)	(0.168)	(0.171)
Total amount of waste (log)	0.684***	0.638***	0.637***
	(0.152)	(0.163)	(0.164)
Rate of recyclables		-1.748*	-1.821*
		(0.954)	(0.958)
Number of *barangay*	0.0110**	0.0151**	0.0130**
	(0.00443)	(0.00604)	(0.00648)
Number of MRF			0.00554*
			(0.00320)
Constant	6.973***	7.264***	7.318***
	(0.608)	(0.598)	(0.585)
Observations	119	95	95
AIC	432.04	358.83	360.11
R-squared	0.551	0.541	0.545

AIC = Akaike Information Criterion, MRF = materials recovery facility.
Notes: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses. (D) represents a dummy variable.
Source: Author's calculation.

A 1% increase in population density raises costs by 0.41%. This indicates that economies of density are observed in the Philippines. A 1% increase in the amount of waste raises costs by 0.64%, which indicates that economies of scale are observed in the Philippines as well. A 1% increase in the rate of recyclables reduces costs by 1.75%, although at the 10% significance level. This indicates that a high rate of recyclables can promote cost savings due to material sales. This result is in contrast to the results obtained in the previous section. On the other hand, an increase in the number of barangays raises costs by 1.3%. An increasing number of barangays might raise transaction costs.

4.5. Concluding Remarks

This study focused on two controversial issues: economies of scale in RWM and the cost efficiency of contracting out to private companies. We conducted simple empirical analyses to clarify the factors that contribute to cost savings at each stage of waste management: collection, intermediate disposal, and final disposal in Japan. The estimation results suggest that economies of scale exist in the collection stage, and indicate that RWM promotes cost savings at the stage as well. However, policymakers should take note that there is an increase in collection costs due to an increasing area. In contrast, economies of scale or cost savings in RWM were not observed at the intermediate and final disposal stages. As shown in Sasao (2019), economies of scale for disposal facilities are expected in the context of siting facilities. In addition, municipalities that previously had high waste disposal costs due to, for example, a small population, may tend to organise inter-municipalities. On the other hand, the results of the grouped models indicate that an increase in population and total amount of treated waste promotes cost savings at the intermediate and final disposal stages in inter-municipalities. The impact on inter-municipalities is stronger than that on municipalities that conduct waste management independently. Therefore, it is important for IMC that a fairly large amount of waste is collected, although policymakers should consider a possible increase in administrative costs.

This study also conducted a simple empirical analysis of MSW management costs in the Philippines. The results found economies of density and of scale in the Philippines. This indicates that IMC can promote cost savings in developing countries' waste management as well. In contrast, the results indicate that an increasing number of *barangays* could increase waste management costs. Policymakers should consider a possible increase in administrative costs due to an increase of the number of constituent municipalities participating in IMC.

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