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Group Collection of Recyclables in Japan

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1. Introduction

To promote a sustainable environment, various recycling programs have been implemented worldwide that have collected a wide variety of materials. From 1992 to 2005, the recycling rate of paper and cardboard increased from 33% to 50% in the United States. Over the same period, the recycling rate of glass increased from 51% to 65% in the European Union (OECD 2008). The recycling industry handles more than 600 million tons of recyclables every year and employs approximately 1.6 million people worldwide (Bureau of International Recycling 2011). These data show that recycling has been successfully integrated into modern economies.

One of the distinguishing features of recycling programs is that support from households is required for their success. Household waste consists of a wide variety of waste products such as paper, glass, organic waste, plastics, textiles, and small chemical waste. In order to recycle waste, households are required to separate part of their heterogeneous waste into homogeneous streams (Aalbers and Vollebergh 2008). Additionally, they have to wash and store recyclables at home before taking them to collection sites on designated collection days. These recycling duties require a lot of effort, and the ability and willingness to engage in such activities vary substantially across households. Bontoux et al. (1996) stated that the most important factor that determines the overall profitability of recycling programs is the cost of collection and sorting of recyclables.

Previous studies based on household-level data have examined the relationship between sociodemographic variables and recycling intensity, with the most commonly examined sociodemographic variables being gender, age, education, and income (Saphores et al. 2006). These authors report that female, senior, well-educated, and wealthy people are more active recyclers. However, they also report that sociodemographic characteristics can only partially explain household recycling behavior (Matsumoto 2011). Thus, recent studies have investigated the determinants of recycling behavior other than sociodemographic variables.

Many recycling programs are powered by volunteers and concerned citizens. Therefore, active community participation is considered to be a key factor for the success of recycling programs. The influence of the local community on household recycling behavior has been extensively studied in the past decade. Bruvoll and Nyborg (2004) and Halvorsen (2008) reported that peer influence could be an important factor in household recycling behavior. These authors further demonstrated that people carry out their recycling duties only when they believe their peers carry out theirs.

Although the role of the community in encouraging recycling activities has been examined at an individual case level, it has not yet been investigated at a municipality level. Thus, the aim of this study is to examine the extent to which the recycling performance of the municipality is improved by community support.

In this study, I focus on group collection programs. In a group collection program, local residents form a recycling group and agree a contract with a waste management company. Residents separate recyclables at home and take them to the collection site on a designated day. The contracted company then collects and transports these recyclables to the centralized recycling station. It is expected that recyclables are collected more efficiently in group collection programs and thereby the overall cost of recycling is reduced. Because of these reasons, many municipalities encourage group collection programs and subsidize recycling groups.

Using annual survey data on solid waste in Japan, I conduct panel data analyses to answer the two research questions: (1) to what extent do group collection programs improve the efficiency of recyclables collection and (2) how much cost is saved if a group collection program is implemented?

The remainder of the paper is organized as follows. Section 2 describes the waste management flow in Japan and explains how group collection programs work. In Section 3, I report the descriptive statistics. In Section 4, I compare recycling efficiency across waste collection methods to show that group collection is an effective approach. In Section 4, I also compare the waste management costs of different approaches. Section 5 concludes the paper.

2. Collection of recyclables

2.1 Waste management flow

Figure 1 shows the waste management flow in Japan. In 2003, the total volume of municipal solid waste generated in Japan was 54,435,686 metric tons. Of this, 165,163 tons of waste were treated (either incinerated or buried) at individual homes.

The first stage of the separation of recyclables is conducted at individual homes. Recyclables are extracted, washed, and collected through the group collection method. The volume of recyclables collected through this method in 2003 was 2,829,003 tons.

The collection of solid waste is the municipality’s responsibility under Japanese law. All waste is collected by the municipality or the waste management company contracted by the municipality. The total volume of waste collected in this way in 2003 was 51,441,520 tons.

The second stage of the separation of recyclables is carried out at waste treatment facilities. Here, recyclables are extracted from the delivery by the municipality. The total volume of recyclables extracted at waste treatment facilities in 2003 was 8,600,214 tons. The volume of recyclables extracted directly from the waste was 2,271,871 tons, while 6,328,343 tons of recyclables were extracted after treatment. The remaining waste was incinerated for reduction. The volume of the final disposal was 8,451,882 tons.

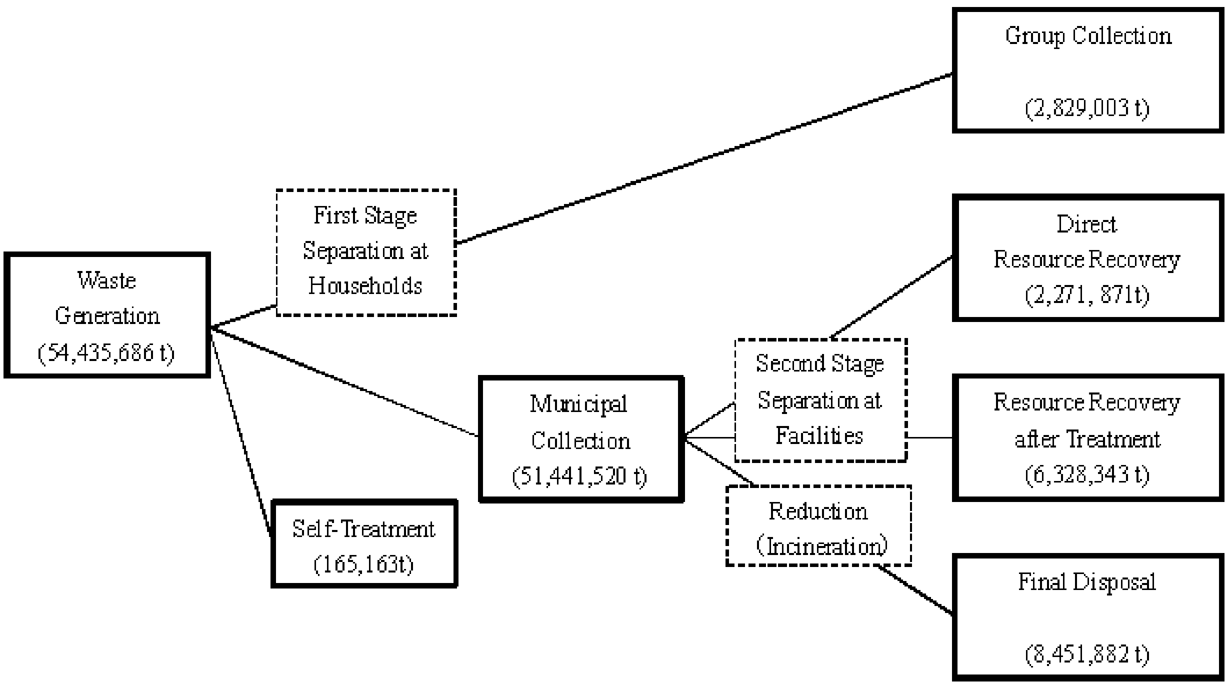

Fig. 1. Waste Management Flowchart for Japan (2003)

2.2 Group collection of recyclables

Table 1 presents the relative share of recyclables extraction in the two stages described above. The share of total recyclables extraction at waste treatment facilities is 69.1%, while the share at individual homes is 30.9%. Paper, metal, and glass are the top three recyclables. Newspapers, magazines, cardboard, and milk cartons are also collected by group collection. A large amount of paper is collected by group collection. Compared with the degree of paper collection, that of metal and glass is relatively minor. (4.1% and 5.8%, respectively).

	Treatment Facility (Municipal Collection)		Individual Homes (Group Collection)	
	Metric tons	(Percentage)	Metric tons	(Percentage)
Total	6,328,343	(69.1%)	2,829,003	(30.9%)
Paper	2,217,419	(45.7%)	2,638,169	(54.3%)
Metal	1,303,260	(95.9%)	55,372	(4.1%)
Glass	865,195	(94.2%)	53,125	(5.8%)
Other	1,942,469	(95.9%)	82,337	(4.1%)

Table 1. Collection Methods and Resource Recovery (2003)

When local residents decide to start a group collection scheme, they form a recycling group. It is common that a preexisting community group such as a parent–teacher association or residents' association adds the role of the recycling group. Once a recycling group is formed, a representative of the group contacts the municipality. Many municipalities encourage their residents to formalize group collection programs, and they provide subsidies according to the volume of recyclables collected.[1]

Picture 1. The Recyclables Collection Process

Once a group collection program starts, residents can bring recyclables to the collection point on a designated day. However, participation in the group collection is voluntary. If residents do not want to participate in the program, they can still dispose of their recyclables. Picture 1 shows how a typical group collection scheme in Japan operates. Households separate recyclables at home and take them to the recycling station. The recyclables are then collected by the waste treatment company contracted by the recycling group. The frequency of collection varies by municipality and type of recyclables.

3. Data

This study used the annual survey of municipal solid waste in Japan as its primary data source. All municipalities record the conditions of waste treatments and recycling activities and report this to the central government. The central government then summarizes the data and publishes it as the annual survey of municipal solid waste. This survey reports the volume of waste collected through each collection method as well as the volume of recyclables extracted from this waste.

These data are downloadable from the website of the Ministry of the Environment (2011). I set the sampling period as 1998 to 2002 for the following reasons. To improve the efficiency of the administrative work of local governments, the central government encouraged the merger of local governments in mid-2000. As a result, the number of municipalities decreased from 3232 in 1999 to 1724 in 2011. This merger of municipalities accelerated after 2003.

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[1] For example, Yokohama City (2011) and Kawasaki City (2011) showed that these cities subsidize recycling groups at the rate of 3 yen/kg.

Recyclables collection (tons) [a]	Average	Standard Deviation
Total	431.16	4354.37
Paper	271.94	3846.15
Metal	−0.67	723.12
Glass	5.49	612.45
Group Collection (tons) [a]	Average	Standard Deviation
Total	68.55	1499.03
Paper	73.04	1375.54
Metal	−1.58	97.69
Glass	−6.24	139.78
Waste Collection (tons) [a]	Average	Standard Deviation
Total	162.65	6549.93
Mixed Garbage	−25.90	2721.71
Burnable Garbage	393.55	11740.62
Unburnable Garbage	−178.98	2258.98
Recyclable Waste	335.29	5107.55
Other Garbage	5.89	477.27
Bulky Garbage	−54.88	1089.98
Direct Delivery	−312.33	17467.91
Cost (1,000 yen) [b]	Average	Standard Deviation
Collection Cost	−900.22	101544.57
Treatment Cost	−1260.23	350340.74
Final Disposal Cost	951.69	106910.88
Outsourcing Cost	20782.36	120189.24
Kumiai Cost	17679.12	515534.36

Note: a: Sample extent: all 3,212 municipalities, all years from 1998 to 2002. b: Sample extent: all 3,212 municipalities, 1998 vs. 2002.

Table 2. Descriptive Statistics of Waste Collection Data (1998-2002)

The descriptive statistics of the data are reported in Table 2. The total amount of recyclables collected in the average municipality increased by 431.16 tons from 1998 to 2002. Group collection increased by 68.55 tons. The group collection of paper increased, while that of metal and glass decreased. In addition to the recyclables collected though group collection, recyclables were also extracted from seven other types of waste: mixed garbage, burnable garbage, unburnable garbage, recyclable waste, other garbage, bulky garbage, and direct delivery. From 1998 to 2002, total waste collection increased by 162.65 tons. The collections of burnable garbage and recyclable waste increased during the sampling period. By contrast, the collections of mixed garbage, unburnable garbage, and bulky garbage decreased.

In the bottom part of Table 2, I compare the costs of waste management between 1998 and 2002. I include five categories of waste management costs: the cost of waste collection, the treatment cost at waste treatment facilities, the final disposal cost, the cost of outsourcing, and the *kumiai* cost (see below). Municipalities often outsource waste management tasks to private companies. The outsourcing cost is the money paid to these private companies. A municipality sometimes forms a *kumiai* (a waste management organization) with other municipalities in order to jointly collect and treat waste. The *kumiai* cost is the cost paid to the *kumiai*. The data show that the collection and treatment costs decreased from 1998 to 2002. By contrast, the remaining three costs increased.

4. Empirical findings

4.1 Impact on recyclables collection

I first examine how much recyclable material is extracted from waste. The composition of waste can vary substantially across municipalities. For example, the share of used paper is large in one municipality, while the share of used glass is large in another. To account for municipality-specific factors, I employ a difference-in-difference model in this paper. Specifically, I estimate the following equation:

$$\Delta R_{it} = \beta_0 + T_t + \beta_g \Delta G_{it} + \beta_w \Delta W_{it} + u_{it} \quad (1)$$

where ΔR_{it} is the change in total recyclables collection, ΔW_{it} is the change in total waste collection and ΔG_{it} is the change in group collection in municipality i at time t. The number of municipalities included in the analysis is 3212 and the sampling period is 1998–2002.

I examine how the change in waste collection is associated with the change in recyclables collection. T_t is the time trend variable, while u_{it} is the error term.[2] As mentioned before, all materials collected through group collection programs are defined as recyclables in the Japanese system. Hence, I impose the condition of $\beta_g = 1$ and estimate equation 1.

The estimation result of equation 1 is reported in the first column of Table 3. As the table shows, the coefficient of the time trend variable is positive and significant. On average, the amount of recyclables collected increased during the sampling period. Based on the estimation result, 21.6% of waste is recycled using municipal collection methods.

Group collection is the most efficient collection method because all collected materials are utilized as recyclable inputs. To compare the efficiency of the other seven collection methods, I estimate the following equation:

$$\Delta R_{it} = \beta_0 + T_t + \beta_g \Delta G_{it} + \boldsymbol{\beta_{wc}} \Delta \boldsymbol{WC_{it}} + u_{it} \quad (2)$$

In equation 2, $\Delta \boldsymbol{WC_{it}}$ is the vector of the changes in the waste collected through these seven collection methods. All generated waste is collected through one of these seven methods.

[2] To account for unobserved heterogeneity, a robust covariance matrix is used in the estimation.

	Total	Collection Methods
Constant	35.321	−0.280
	(79.724)	(31.819)
Time Trend	144.951**	62.304**
	(29.111)	(11.664)
Group Collection (Fixed Parameter)	1.000	1.000
Municipal Collection		
Total	0.216**	
	(0.005)	
Mixed Garbage		0.025**
		(0.005)
Burnable Garbage		−0.066**
		(0.004)
Unburnable Garbage		−0.043**
		(0.007)
Recyclable Waste		0.633**
		(0.006)
Other Garbage		0.105**
		(0.028)
Bulky Garbage		0.129**
		(0.014)
Direct Delivery		−0.065**
		(0.003)
Adjusted R^2	0.282	0.886

Note: Standard errors in parentheses. Superscript * and ** denote significance at 5% and 1%, respectively. Sample extent: all 3,212 municipalities, all years from 1998 to 2002.

Table 3. Efficiency comparison across collection methods: aggregated recyclables (OLS model, N = 12,848)

The amount of recyclables always increases as the volume of collected waste increases. However, if recyclables are collected through an inefficient collection method (e.g., if paper is collected as mixed garbage rather than as recyclable waste), then the overall recycling efficiency decreases. Since the recycling efficiency of the mixed garbage method is much lower than that of the recyclable waste method, the total amount of paper recycled decreases. If the indirect effect of the collection method change dominates the direct effect of the waste increase, then I obtain $\beta_{wc} < 0$.

The estimation result of equation 2 is presented in the second column of Table 3. The most efficient municipal collection method is recyclable waste as expected. Approximately 63% of the waste collected through this method is recycled.

The second most efficient method is bulky garbage collection. Approximately 13% of this category of waste is recycled. These recyclables can be mixed with burnable and unburnable garbage, but their extraction is difficult. Therefore, as the volume of this garbage increases, the overall recycling efficiency is reduced.

	Paper	Metal	Glass
Constant	−26.012	56.310**	2.410
	(18.771)	(12.702)	(8.209)
Time Trend	20.497**	−8.657	−12.090**
	(6.881)	(4.656)	(3.009)
Group Collection (Fixed Parameter)	1.000	1.000	1.000
Municipal Collection			
Mixed Garbage	−0.026**	0.025**	−0.006**
	(0.003)	(0.002)	(0.001)
Burnable Garbage	0.004	0.007**	−0.034**
	(0.002)	(0.001)	(0.001)
Unburnable Garbage	0.076**	−0.070**	0.036**
	(0.004)	(0.003)	(0.002)
Recyclable Waste	0.532**	−0.174**	0.193**
	(0.004)	(0.002)	(0.002)
Other Garbage	−0.043*	−0.014	0.007
	(0.017)	(0.011)	(0.007)
Bulky Garbage	0.152**	0.068**	0.010**
	(0.008)	(0.006)	(0.004)
Direct Delivery	−0.048**	−0.044**	0.016**
	(0.002)	(0.001)	(0.001)
Adjusted R^2	0.947	0.309	0.615

Note: Standard errors in parentheses. Superscript * and ** denote significance at 5% and 1%, respectively. Sample extent: all 3,212 municipalities, all years from 1998 to 2002.

Table 4. Efficiency comparison across collection methods: paper, metal, and glass (SURE model, N = 12,848)

As presented in Section 2.2, paper, metal, and glass are the top three categories of recyclables. I now evaluate the extraction efficiencies of these three categories based on the following seemingly unrelated linear regression equations (SURE) model:

$$\Delta R_p = \boldsymbol{\beta}_p \boldsymbol{X}_p + u_p \quad \text{(3-a)}$$

$$\Delta R_m = \boldsymbol{\beta}_m \boldsymbol{X}_m + u_m \quad \text{(3-b)}$$

$$\Delta R_g = \boldsymbol{\beta}_g \boldsymbol{X}_g + u_g \quad \text{(3-c)}$$

$$\mathrm{E}[u_j | \boldsymbol{X}_p, \boldsymbol{X}_m, \boldsymbol{X}_g] = 0 \quad \text{(3-d)}$$

$$\mathrm{E}[u_j \cdot u'_k | \boldsymbol{X}_p, \boldsymbol{X}_m, \boldsymbol{X}_g] = \sigma_{jk} \cdot \boldsymbol{I} \quad \text{(3-e)}$$

where $\boldsymbol{\beta}_j \boldsymbol{X}_j = \beta_{0j} + T_j + \beta_{Gj}\Delta G_j + \boldsymbol{\beta}_{wcj}\Delta \boldsymbol{WC}$. It is assumed that the marginal impact of waste increase on recyclables collection varies across recyclables. The disturbances across equations are allowed to be correlated.

The estimation results of equation 3 are presented in Table 4. I imposed the condition of $\beta_{gj} = 1$ as before. The first column shows that paper is extracted from the recyclable waste (53.2%) and bulky garbage (15.2%) methods. By contrast, the coefficients of mixed garbage, other garbage, and direct delivery are negative. This result implies that the extraction of paper becomes difficult once it is mixed with other waste. Metal is extracted from mixed garbage (2.5%), burnable garbage (0.7%), and bulky garbage (0.7%). The coefficient of recyclable waste is negative and statistically significant. Together with the fact that most metal is collected through municipal collection, the separation of metal is not important for recycling efficiency. Metal is extracted at treatment facilities anyway. Glass is extracted from unburnable garbage (3.6%), recyclable waste (19.3%), bulky garbage (1.0%), and direct delivery (1.6%). Unlike metal, this result shows that waste separation is important for glass recycling.

4.2 Impact on waste management costs

To compare the costs of waste management, I include five cost categories: the cost of waste collection, the treatment cost at waste treatment facilities, the final disposal cost, the cost of outsourcing, and the *kumiai* cost. I compare the waste management costs in 1998 with those in 2001 to examine how increases in waste collections are associated with increases in waste management costs.

For this empirical estimation, I use the following seemingly unrelated regression model:

$$\Delta C_{CL} = \boldsymbol{\gamma}_{\boldsymbol{CL}} \boldsymbol{X}_{CL} + u_{CL} \quad \text{(4-a)}$$

$$\Delta C_{TR} = \boldsymbol{\gamma}_{\boldsymbol{RL}} \boldsymbol{X}_{TR} + u_{TR} \quad \text{(4-b)}$$

$$\Delta C_{FD} = \boldsymbol{\gamma}_{\boldsymbol{FD}} \boldsymbol{X}_{FD} + u_{FD} \quad \text{(4-c)}$$

$$\Delta C_{OS} = \boldsymbol{\gamma}_{\boldsymbol{OS}} \boldsymbol{X}_{OS} + u_{OS} \quad \text{(4-d)}$$

$$\Delta C_{KU} = \boldsymbol{\gamma}_{\boldsymbol{KU}} \boldsymbol{X}_{KU} + u_{KU} \quad \text{(4-e)}$$

$$\mathrm{E}[u_j | \boldsymbol{X}_{CL}, \boldsymbol{X}_{TR}, \boldsymbol{X}_{FD}, \boldsymbol{X}_{OS}, \boldsymbol{X}_{KU}] = 0 \quad \text{(4-f)}$$

$$\mathrm{E}[u_j \cdot u'_k | \boldsymbol{X}_{CL}, \boldsymbol{X}_{TR}, \boldsymbol{X}_{FD}, \boldsymbol{X}_{OS}, \boldsymbol{X}_{KU}] = \sigma_{jk} \cdot \boldsymbol{I} \quad \text{(4-g)}$$

where $\gamma_j \boldsymbol{X}_j = \gamma_{0j} + \gamma_{Gj}\Delta G_j + \boldsymbol{\gamma}_{wcj}\Delta \boldsymbol{WC}$.

The estimation result of equation 4 is reported in Table 5. This table shows that the impact of waste collection method on waste management costs varies. The cost of waste collection increases as the volume of mixed garbage increases. Based on this result, the cost of mixed garbage collection is 988 yen/ton. By contrast, I find that cost decreases as the volume of burnable garbage increases.

Treatment cost increases as the volume of mixed garbage increases. Based on this result, the average treatment cost of mixed garbage is 6304 yen/ton. By contrast, treatment cost decreases as the volume of recyclable waste and bulky garbage increases. The reductions in treatment cost are 24,830 yen/ton for recyclable garbage and 36,424 yen/ton for bulky garbage.

The final disposal cost increases as the volumes of mixed garbage, recyclable waste, direct delivery, and group collection increase. This result suggests that a certain proportion of the materials collected as recyclables end up in landfill. Based on these results, the final disposal cost of recyclable waste is 3464 yen/ton, while that of group collection is 11,385 yen/ton.

As discussed, municipalities outsource such waste management tasks to private companies. Table 5 shows that the outsourcing cost increases as the volumes of recyclable waste and group collection increase. The costs are 16,725 yen/ton for recyclable waste and 13,257 yen/ton for group collection.

	Collection	Treatment	Disposal	Outsource	*Kumiai*
Constant	4030.4**	11509.3**	452.9	13437.5**	−2620.2
	(1198.3)	(1573.4)	(1495.2)	(1585.6)	(1830.4)
Mixed	0.988**	6.304**	4.097**	1.281**	−1.833**
Garbage	(0.362)	(0.475)	(0.452)	(0.479)	(0.553)
Burnable	−2.826**	−7.882**	−2.394**	−5.957**	12.833**
Garbage	(0.308)	(0.404)	(0.384)	(0.407)	(0.470)
Unburnable	0.170	−4.755**	0.468	−2.029*	5.605**
Garbage	(0.606)	(0.796)	(0.756)	(0.802)	(0.926)
Recyclable	−6.770**	−24.830**	3.464**	16.725**	31.869**
Waste	(0.570)	(0.748)	(0.711)	(0.754)	(0.870)
Other	−5.978	−13.873**	−6.743	−1.017	1.453
Garbage	(3.093)	(4.062)	(3.860)	(4.093)	(4.725)
Bulky	1.710	−36.424**	−0.867	−10.182**	32.376**
Garbage	(1.102)	(1.447)	(1.375)	(1.459)	(1.684)
Direct	0.550*	7.590**	3.147**	4.605**	−12.120**
Delivery	(0.271)	(0.356)	(0.338)	(0.359)	(0.414)
Group	0.008	−2.698**	11.385**	13.257**	8.681**
Collection	(0.788)	(1.034)	(0.983)	(1.042)	(1.203)
Adjusted R^2	0.578	0.939	0.407	0.473	0.962

Note: Standard errors in parentheses. Superscript * and ** denote significance at 5% and 1%, respectively.

Table 5. Cost Comparison across Collection Methods. (SURE model, N=3212)

I also estimated the impact of waste collection on the *kumiai* cost. Increases in recyclable waste, bulky garbage, and group collection lead to an increase in the *kumiai* cost. The costs are 31,869 yen/ton for recyclable waste and 8681 yen/ton for group collection.

Most recyclables are collected through either recyclable waste or group collection. The total cost of the recyclable waste method is 20,458 yen/ton, while that of the group collection method is 30,633 yen/ton. Therefore, the total waste management cost of the group collection method is higher than is that of the recyclable waste method. The benefits of the recyclable waste method, however, heavily rely on cost reductions at the treatment facilities. If the advantage of the treatment cost is removed, then the costs of the recyclable waste method jump to 52,058 yen/ton.

5. Conclusion

The vast majority of municipalities in Japan encourage their residents to use group collection programs, and some municipalities even provide financial support. In this paper, I evaluated such group collection programs based on two efficiency criteria: recycling and cost.

I examined how a change in waste collection method is associated with a change in recyclables collection and found that mixing recyclables with unsorted waste lowers the efficiency of recyclables extraction. In group collection programs, recyclables are separated at home and the mixing of recyclables with unsorted waste can be avoided. Therefore, group collection is the most efficient collection method. Based on the presented empirical findings, the second most efficient collection method is the recyclable waste method. Approximately 63% of waste collected in this way is transformed into recycling inputs. The extraction rate of recyclables becomes much lower if recyclables are collected using other methods. By utilizing group collection programs, more recyclables are obtained.

To evaluate cost efficiency across collection methods, I estimated the impact of waste collection on waste management costs. I included five varieties of waste management costs in the analysis: the cost of waste collection, the treatment cost at waste treatment facilities, the final disposal cost, the outsourcing cost, and the *kumiai* cost. The empirical results showed that the impact of waste collection varies across waste types as well as collection methods. Based on the estimation results, the cost of recycling using the municipal collection method is 20,458 yen/ton. By contrast, the cost using the group collection method is 33,323 yen/ton.

However, because the extraction rate of recyclable waste is 0.63, the net cost of municipal collection is actually 32,473 yen/ton (20,458/0.63). This implies that the cost of recyclables extraction is about the same for group and municipal collections. Contrary to the common assumption that the cost of recycling is reduced by implementing group collection programs, the findings of this paper suggest that the costs are similar.

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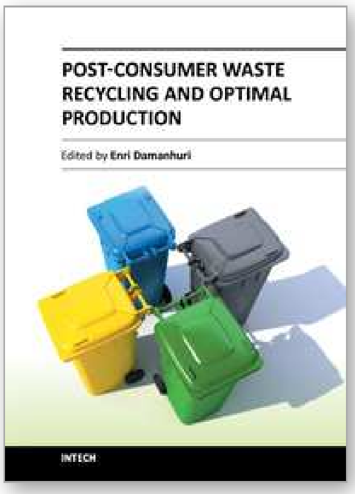

Post-Consumer Waste Recycling and Optimal Production
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This book deals with several aspects of waste material recycling. It is divided into three sections. The first section explains the roles of stakeholders, both informal and formal sectors, in post-consumer waste activities. It also discusses waste collection programs for recycling. The second section discusses the analysis tools for recycling system. The third section focuses on the recycling process and optimal production. I hope that this book will convey both the need and means for recycling and resource conservation activities to a wide readership, at both academician and professional level, and contribute to the creation of a sound material-cycle society.