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Estimation of garbage reduction and recycling promotion under the Containers and Packaging Recycling Law and garbage pricing

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Abstract This article examines the reducing and recycling effects caused by municipal solid waste policies, such as garbage pricing and recyclables collection. Equations for garbage and recyclables are estimated using Heckman's two-step estimation and seemingly unrelated regression (SUR) to consider sample selection bias and the correlation between garbage and recyclables emission. The estimation results suggest that municipal PET bottle collection leads to a reduction in the amount of garbage collected. Furthermore, the results reveal that garbage pricing increases the quantity of PET bottles collected, while it decreases the amount of garbage.

Key words Containers and packaging recycling law · Garbage pricing · Garbage reduction · Recycling

1 Introduction

There is an urgency in Japan to establish a recycling-based society owing to the shortage of landfill sites for waste disposal. To accomplish this national target, the Japanese government has encouraged the reducing, reusing, and recycling of waste with the slogan "3R" under the Basic Law for Establishing a Recycling-Based Society. Since the 1990s, several types of recycling laws along with the slogan have been enacted and various policies have been implemented in Japan. These laws include the Legislation for Automobile Recycling, Construction Material Recycling Act, Home Appliance Recycling Law, and Food Recycling Law. Among these laws, the Containers and Packaging Recycling Law enacted in 1997 appears to be the most important; this is because containers and packaging wastes[1] account for a large share of emitted waste with respect to cubic capacity. Under this law, the collection of each type of recyclable was at the discretion of the municipalities.

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[1] This study refers to the containers and packaging wastes that are designated by the law as "recyclables."

In addition to the national policy on recyclables collection, as outlined by the law, many Japanese municipalities have been practicing unit-based garbage[2] pricing as an independent regional policy for a long time. This regional policy has also aimed to reduce general waste and save the scarce landfill sites. Under the garbage pricing policy, citizens are required to dispose of waste using designated bags or tags that include a disposal fee in the purchase price. Typically, citizens are charged by the bags and tags depending on how many she or he disposes of burnable, nonburnable, and mixed wastes. Each municipality can arbitrarily determine the level of the purchase price for the designated bags and tags. In contrast, charges are not usually levied on recyclables that are separated from waste. Thus, garbage pricing provides citizens with an economic incentive to reduce waste by sorting recyclables that can be disposed of free of charge. In this manner, garbage pricing is expected to reduce the flow of solid waste by encouraging citizens to sort waste into recyclables.

There is extensive empirical literature on solid waste generation and the incentive for recycling created by garbage pricing. For example, Reschovsky and Stone (1994) examined the probability of recycling by household, using individual data on recyclables material emission. However, data pertaining to the garbage price was employed as a dummy variable in a regression equation, and not as continuous and actual level data in the analysis. Kinnaman and Fullerton (2000) applied a simple microeconomic foundation to the households' behavior with respect to waste discharge and recycling and estimated demand equations for garbage and recyclables, regarding the garbage price and the curbside recycling policy as endogenous variables. Jenkins et al. (2003) investigated the relationship between the discrete data of the recycling effort of recyclable materials and the garbage price level using an ordered probit model. The effect of garbage pricing on waste reduction in Japan has also been estimated in many other studies, such as Sasao (2000) and Usui (2003). Yamaya (2000) pointed out that the introduction of garbage pricing by bags and tags also encouraged citizens to separate recyclables from waste.

However, the abovementioned studies did not examine the crossing effects of garbage pricing and recyclables collection on garbage and recyclables emission. For instance, if only the garbage pricing policy is implemented, its effect on recycling of waste may be limited because the recyclables may not be collected. Similarly, if only the recyclables collection outlined by the law is executed, citizens may have little incentive to separate recyclables from waste, and consequently, the amount of collected recyclables and the reduction of garbage may be lesser than expected. On the other hand, when both recyclables collection and garbage pricing are implemented simultaneously, such a mixed policy may lead effectively to the reduction of garbage emission and the increase in recyclables collection. The effects of recyclables collection and garbage pricing on 3R appear to complement each other. Therefore, it seems interesting to

[2] In this article, the burnable, nonburnable, and mixed wastes are referred to as "garbage." Therefore, waste includes both "garbage" and "recyclables."

identify the recycling effect by garbage pricing and the garbage-reducing effect caused by recyclables collection as outlined by the Containers and Packaging Recycling Law.

Therefore, this article primarily aims to investigate how garbage pricing affects the amount of garbage emission and recyclables collection as well as how the implementation of recyclables collection affects both amounts. This investigation was conducted using an econometric estimation for the garbage and recyclables equations based on Japanese municipal waste management data. For all Japanese municipalities, data pertaining to the unit-based price were accumulated by mail and phone surveys; these surveys inquired about the purchasing prices for bags or the corresponding tags. In the estimation process, Heckman's two-step model was employed to resolve sample selection bias. With regard to the estimation for the recyclable and garbage regression equations, seemingly unrelated regression (SUR) was employed to consider the two as a system of regression equations. A comparison of the estimation results for the coefficient of price of bags and tags in the two regression equations enables an assessment of the substitution effect between garbage and recyclables emission caused by the garbage pricing. According to the estimation results in this study, the municipal decision to collect poly(ethylene terephthalate) (PET) bottles leads to a reduction in garbage. Furthermore, the higher the price of bags and tags, the greater is the quantity of PET bottles collected.

This article is divided into the following six sections. The next section provides the specification of the data utilized in this study. The third section describes the econometric model employed, and the fourth section presents the estimation results in detail. The fifth section discusses the policy implications derived from the estimation result. Finally, the last section includes the concluding remarks.

2 Data

In this study, data pertaining to the amount of containers and packaging recyclables with respect to Japanese municipalities were derived from "The Results of Collection and Recycled Products under the Containers and Packaging Recycling Law, in the 1997 Fiscal Year," issued by the Ministry of Environment, Japan (1998).[3] In this study, we refer to the collected amount of containers and packaging recyclables with respect to municipalities as "recyclables."

Data regarding the garbage emission of each municipality for the 1997 fiscal year were provided by Japan Waste Management Association (2000). The data of municipal garbage emission were derived from these statistics, using the fol-

[3] The type of containers and packaging recyclables collected is at the discretion of the municipalities; they can choose from among the four recyclables (glass bottles, PET bottles, cans, and paper containers) designated by the Containers and Packaging Recycling Law. Therefore, data regarding the collected amount of each recyclable material is only available for those municipalities that collect it. In this study, "glass bottles" refers to the total amount of colorless, brown-colored, and any other color bottles. "Cans" refers to the sum of steel and aluminum can collection.

lowing process. According to the statistics, the amount of municipal garbage emission is shown as "the amount of garbage collection" (*syusyu ryo*). This amount includes "burnable waste" (*kanen gomi*), "nonburnable waste" (*funen gomi*),[4] "mixed waste" (*kongo gomi*), "resource garbage" (*shigen gomi*), "other waste" (*sonota gomi*), and "bulky waste" (*sodai gomi ryo*).[5] In this study, the amount of containers and packaging recyclables as well as that of bulky waste is subtracted from the amount of garbage collection in order to obtain appropriate data with respect to the amount of municipal garbage emission. The amount of garbage collection may include containers and packaging recyclables; this is because resource garbage, which is one of the constituents of the amount of garbage collection, may include containers and packaging recyclables. In addition, bulky waste, which is included in "the amount of garbage collection," is not charged according to the unit-based price. Therefore, it has not been considered in this study. The amount of municipal garbage emission derived from this process is hereafter referred to as "garbage."

Garbage and recyclables in this study include both "household waste" (*seikatsu kei gomi*) and "business waste" (*jigyo kei gomi*). Although the amounts of household and business wastes should typically be examined separately, the data of garbage and recyclables were not divided in our data in 1997. Consequently, in this study, we have employed data combining both household and business wastes.[6] In addition, other municipal environmental policy data such as the rate of landfill have been derived from Japan Waste Management Association (1999, 2000).

In this study, we gathered data on garbage pricing for all Japanese municipalities. The data were collected using a process involving several steps. First, using the data from Japan Waste Management Association (2000), we identified the municipalities that had imposed garbage pricing. Subsequently, we conducted mail and telephone surveys to investigate the price of a 45-l bag or the corresponding tag used to levy a fee on the garbage.[7] The municipal price of a 45-l bag or the corresponding tag is referred to as the "price of bags and tags" in this study. It should be noted that these data pertaining to garbage pricing were imposed on burnable and mixed wastes in each municipality. We were unable to

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[4] In Japan, garbage is basically divided into burnable waste and nonburnable waste. The former is burned in an incinerator, while the latter is buried in a landfill site.

[5] The amount of garbage collection (*syusyu ryo*) does not include the following: (1) "self-disposal" (*jikasyori ryo*), (2) "recyclables collected by voluntary groups" (*syudan kaisyu ryo*), and (3) "the amount carried into municipal facilities" (*chokusetsu hannyu ryo*).

[6] Using the summation of household and business wastes in the analysis has the following advantage. Garbage pricing may trigger citizens to transfer their household waste to business waste, although such a transfer is illegal. However, in our data, such transfers are inconsequential because the amount of waste transferred from household waste to business waste is negated, and the levels of garbage and recyclables remain almost constant during shift.

[7] All the data were collected during the survey period from July 2001 to January 2002. The collected price data correspond to the 2001 fiscal year. Although it would have been more appropriate to use the price data for the 1997 fiscal year, we were unable to collect this data because certain municipalities had lost this data.

obtain price data for nonburnable waste due to the difficulty in data gathering. Therefore, garbage price in this study was not imposed on nonburnable waste. This may suggest that our data for the price of bags and tags appears insufficient. However, most of the municipalities introduced garbage pricing on nonburnable waste as well as burnable waste, although the level of these prices may have differed. Therefore, we consider that our price data is sufficient for examining the substitution effect between garbage and recyclables under garbage pricing, which is main interest of our study.

Socioeconomic data with respect to all municipalities was obtained from Asahi Newspaper (2003). This data included taxable gain per capita, average household size, number of residents over the age of 65, population density, number of employees engaged in primary and tertiary industries, the number of offices per capita, and so on. Descriptive statistics for this data are provided in Table 1.

3 Econometric model

This section describes the econometric model used to investigate how the amounts of garbage emission and recyclables collection were determined. Using the model, we examined the effects of garbage pricing and the implementation of the collection of the four recyclables (glass bottles, PET bottles, cans, and paper containers) on the quantity of garbage and recyclable materials. Thus, the main focus of this study is the substitution effect between garbage and recyclables through garbage pricing and recyclables collection.

In 1997, approximately 40% of the municipalities did not collect any containers and packaging recyclables (recyclables). We have excluded these municipalities from our econometric analysis because the substitution effect between garbage and recyclables cannot be examined if a municipality does not collect recyclables. However, as is well known among econometricians, such exclusion causes an additional problem. Selecting a sample based on a certain criteria results in sample selection bias and the estimator's consistency is affected. To resolve this problem, we employed Heckman's two-step estimation method (Heckman 1979; Amemiya 1985). In the first step, we employed a probit estimation to identify the factors that affect the municipality's decision concerning recyclables collection. In the second step, we added an inverse Mill's ratio, derived from the probit estimation, to the explanatory variables in both garbage and recyclables regression equations; consequently, we obtained a consistent estimator in the two regression equations.

In the first step, the following probit estimation is implemented:

$$C_i = l[z_i'\alpha + \varepsilon_{0i} > 0]$$

where the subscript i indicates the municipality number, C_i is the dummy variable for municipal recyclables collection, $l[\cdot]$ is the indicator function,[8] α is the

[8] The indicator function being unity when the statement in brackets is true, otherwise zero. See the Appendix.

Table 1. Data summary

Variables	Mean	SD	Definition
Municipal socioeconomic variables			
Taxable gain	1.194	0.304	Taxable gain per capita (million yen)
Household size	3.175	0.481	Average household size
Over 65	0.215	0.0652	Rate of resident over 65 years old
Population density	598.227	1292.174	Population density of municipalities
Primary industry	0.169	0.119	Rate of employee engaged in primary industry in 1995
Tertiary industry	0.495	0.109	Rate of employee engaged in tertiary industry in 1995
Office	0.396	0.125	Number of offices per capita in 1996
Municipal waste management variables			
Garbage	634.060	324.501	Amount of garbage per capita per day (g)
Recyclables	21.663	32.625	Amount of recyclables collected per capita per day (g)
Public rate	0.187	0.346	Rate of public sector waste collection in 1996
Disposal cost	0.0158	0.0120	Rate of solid waste disposal cost per budget expenditure in 1996
Landfill	0.271	0.192	Direct landfill rate in 1996
Weighbridge	0.682		Dummy variable for weighbridge usage
Price of bags and tags	7.205	17.938	Price per 45-l bag (yen)[a]
Two tier pricing	0.0567		Dummy variable for two-tier pricing
Flat-rate pricing	0.0786		Dummy variable for flat-rate pricing
Other pricing	0.0761		Dummy variable for other pricing
Garbage frequency	2.114	0.737	Collection frequency of burnable and mixed waste (per week)
Resource frequency	1.522	1.602	Collection frequency of resource garbage (per week)
Collection	0.606		Dummy variable for recyclables collection[b]
Glass	0.414		Dummy variable for glass bottles collection[b]
PET bottles	0.169		Dummy variable for PET bottles collection[b]
Cans	0.590		Dummy variable for steel and aluminum can collection[b]
Paper containers	0.313		Dummy variable for paper containers collection[b]
Number of observations			3208

Data corresponds to 1997 fiscal year if data year is not described in the definition
SD, Standard deviation; PET, poly(ethylene terephthalate)
[a]The value is set at 5 yen per bag for nonpricing municipalities
[b]They become one if collected by the municipality, otherwise zero

parameter vector,[9] and ε_{0i} is the error term. z_i is the vector of socioeconomic variables that affect the municipality's decision concerning recyclables collection, including a municipal demographic factor and waste management variables such as the rate of landfill. The inverse Mill's ratio is derived from this probit model. Details pertaining to the econometric assumption are provided in the Appendix. The estimation is implemented using the probit command in TSP version 4.5.

"Recyclables" refers to the sum of the amounts of the four recyclables collected. Undoubtedly, the amount of recyclables depends on how many of the four different types of containers and packaging recyclables are collected. Therefore, the plausible explanatory variables in the regression equation that determines the amount of recyclables are the four dummy variables that indicate the collection of each recyclable material (i.e., glass bottles, PET bottles, cans, and paper containers). In this study, the effects of the four dummy variables for recyclables collection on the total amount are assumed to depend on the level of garbage pricing. When a municipality decides to collect particular containers and packaging recyclables, its amount discharged by citizens appears to depend on the price of bags and tags. This is because a citizen may produce more recyclables under higher garbage pricing levels to reduce the cost of garbage discharge. In addition, this study employs socioeconomic factors as explanatory variables.[10] Additionally, the inverse Mill's ratio is added to the explanatory variables in order to resolve sample selection bias. Thus, the recyclables regression equation is as follows:

$$R_i = x_{1i}'\beta_1 + d_i'\delta_{1i} + \rho_1\lambda_i + \varepsilon_{1i}, \quad \delta_{1i} = \gamma_0 + \gamma_1 p_i \tag{1}$$

where R_i is the recyclables, x_{1i} is the vector of the explanatory variables including municipal demographic factors and variable for other municipal waste management, d_i is the collection dummy variable vector of the four recyclables, λ_i is the inverse Mill's ratio, p_i is the price of bags and tags, ε_{1i} is the error term, and β_1, γ_0, γ_1, and ρ_1 are parameter vectors and parameter, respectively.

The following regression Eq. 2 represents the quantity of garbage disposed of by individuals in each municipality.

$$G_i = x_{2i}'\beta_2 + d_i'\delta_2 + \rho_2\lambda_i + \varepsilon_{2i} \tag{2}$$

where G_i is the amount of garbage emission per capita per day (grams), x_{2i} is the explanatory variables that are likely to affect the quantity of garbage including municipal demographic factor and variables for garbage pricing and variable for other municipal waste management, ε_{2i} is the error term, and β_2, δ_2, and ρ_2 are parameter vectors and parameter, respectively.

[9] In this study, all vectors are set as column form, and prime symbol indicates transpose of vector.

[10] The coefficients of the four dummy variables for containers and packaging recyclables collection should ideally depend on other socioeconomic variables. However, the other socioeconomic variables have not been related to the coefficients of the four dummy variables to avoid multicollinearity.

It is highly probable that other unobserved characteristics of the municipalities affect the amount of both garbage and recyclables. For example, the citizen's characteristics regarding environmental awareness or consumption culture may have a regional difference. Such factors seem to affect both garbage and recyclables discharge behaviors, while they are usually unobservable for researchers. Thus, the disturbance terms of both regression Eqs. 1 and 2 can be regarded as being correlated. Therefore, it appears reasonable to allow for the correlation of the two error terms. Following this assumption, the error terms ε_{1i} and ε_{2i} are correlated. When the error terms of the two equations are correlated, an ordinary least-squares estimator for each equation is no longer asymptotically efficient (see Greene 2000, Chap. 15). To resolve this problem, the seemingly unrelated regression (SUR) is usually employed in an econometric study. This estimation method is implemented in this study using the SUR command in TSP version 4.5.

4 Results

Table 2 presents the estimation results of the probit estimation in the first step. The estimation results of the coefficient for the demographic variable indicate some information pertaining to the municipal decision concerning recyclable collection; the log of Taxable gain has a positive effect on the municipal decision concerning recyclables collection. This suggests that a municipality with a higher income level is inclined toward recyclables collection. The coefficients for the log of Population density and the log of Office were estimated positively. These results indicate that recyclables collection tends to be implemented in urban areas. However, the coefficients for Primary industry and Tertiary industry were estimated negatively. This implies that the higher the number of employees

Table 2. Estimation results of probit analysis for recyclable materials collection

Explanatory variables	Estimates
Constant	–0.00665 (–0.0133)
Log(Taxable gain)	0.480*** (3.229)
Log(Household size)	0.372* (1.810)
Log(Population density)	0.0765*** (2.996)
Over 65	0.167 (0.267)
First industry	–0.707** (–2.137)
Third industry	–0.795** (–2.099)
Log(Office)	0.270*** (2.842)
Public rate	0.354*** (5.032)
Disposal cost	9.067*** (2.785)
Landfill	–0.251* (–1.948)
Log likelihood	–2016.08
N	3208

The numbers in parentheses are *t*-ratios
*** $P < 0.01$; ** $P < 0.05$; * $P < 0.1$

engaged in a secondary industry, the greater is the chance of a municipality collecting recyclables. Furthermore, the results for the waste management variables shed more light on the issue. We employed data from the previous fiscal year for theses variables. The coefficient for Landfill was estimated negatively. This suggests that a municipality that has a higher rate of direct landfill in the previous fiscal year will hesitate to collect recyclables. On the other hand, the level of the cost of solid waste disposal per municipal budget expenditure in the previous fiscal year had a positive effect.

Table 3 provides the estimation results of the SUR for the collected amounts of recyclables and garbage. In this study, we examined two models of the recyclables and garbage equations. In the first model, all socioeconomic variables and waste management policy variables were employed in recyclables Eq. 1 and garbage Eq. 2. The results for this model correspond to the "Full model" in the tables. The second model, or "Selected model," excludes all explanatory variables that were not significant based on the results of the Full model. The signs of the estimated coefficients were almost identical in both models.

The estimation result shows that the log of Taxable gain had a negative effect on the garbage emission. This suggests that a municipality with a higher income level discharges less garbage per capita. The log of Household size, which indicates the average household size in a municipality, had a negative effect on garbage emission. In other words, because family members share daily necessities among themselves, a larger household size seems to make a per capita consumption of these necessities smaller, resulting in a smaller garbage emission per capita. The log of Population density had negative effects on both recyclables and garbage discharge. This fact suggests that the lifestyle of an individual in an urban area may lead to smaller amounts of recyclables and garbage being produced. The number of residents over the age of 65 was significantly positive to recyclables emission, while it was significantly negative to garbage emission. Perhaps, these results are caused not only by the consumption preferences and lifestyle of the older generation, but also by the lower opportunity cost of a retired person, which induces him or her to sort waste and recycle it. Moreover, a higher frequency of garbage collection had a positive effect; in other words, a higher frequency is likely to facilitate the disposal of garbage for citizens. Given the fact that the dependent variables in this study included business waste, we employed additional variables that may affect the amount of recyclables and garbage in business waste, including the number of employees engaged in primary and tertiary industries and the number of offices per capita. The estimation results of these variables indicated that the coefficient for Primary industry and Tertiary industry were estimated positively in both equations. This suggests that the discharge of garbage and recyclables in a municipality with a high number of employees engaged in a secondary industry tends to be low. Contrarily, the larger the number of offices per capita, the greater is the amount of garbage per capita. The result implies that a municipality in a business area tends to discharge more garbage. In 1997, the amounts of recyclables and garbage were not measured using a weighbridge in certain municipalities. In such municipalities, the

Table 3. Estimation results of recyclables and garbage

	Recyclables		Garbage	
Explanatory variables	Full model	Selected model	Full model	Selected model
Constant	–14.721	–26.069**	1308.07***	1287.85***
	(–0.770)	(–2.428)	(10.428)	(10.659)
Log(Taxable gain)	–8.319		–167.094***	–167.424***
	(–1.479)		(–4.532)	(–4.605)
Log(Household size)	–2.150		–487.797***	–500.123***
	(–0.312)		(–10.725)	(–11.159)
Log(Population density)	–2.834***	–2.441***	–22.915***	–23.262***
	(–2.938)	(–2.904)	(–3.616)	(–3.695)
Over 65	80.834***	90.601***	–1093.91***	–1111.36***
	(3.669)	(4.653)	(–7.541)	(–7.7089)
Primary industry	32.994***	35.167***	271.296***	272.237***
	(2.805)	(3.025)	(3.512)	(3.523)
Tertiary industry	49.339***	49.450***	1097.39***	1097.11***
	(4.112)	(5.113)	(13.930)	(13.983)
Log(Office)	–0.390		214.856***	214.087***
	(–0.123)		(10.370)	(10.417)
Resource Frequency	0.308			
	(0.628)			
Garbage frequency			73.346***	72.733***
			(11.043)	(10.982)
Weighbridge	5.011***	5.114***	–31.938***	–33.167***
	(3.068)	(3.159)	(–2.984)	(–3.102)
Price of bags and tags			–2.789***	–2.804***
			(–8.484)	(–8.683)
Two-tier pricing			31.374	
			(1.570)	
Flat-rate pricing			–14.995	
			(–0.777)	
Other pricing			–84.123***	–82.828***
			(–4.454)	(–4.417)
Glass	26.524***	25.198***	–11.201	
	(12.818)	(15.176)	(–0.989)	
Glass · Price	–0.118			
	(–1.157)			
PET bottles	1.541		–34.778***	–34.982***
	(0.661)		(–2.837)	(–3.110)
PET bottles · Price	0.512***	0.537***		
	(3.140)	(4.708)		
Cans	15.879***	15.409***	–41.535	
	(3.304)	(3.309)	(–1.341)	
Cans · Price	0.0619			
	(0.703)			
Paper containers	–1.874		2.048	
	(–0.943)		(0.189)	
Paper containers · Price	0.0501			
	(0.469)			
Inverse Mill's ratio	–25.348***	–17.937***	–270.740***	–278.283***
	(–2.838)	(–2.635)	(–4.629)	(–4.766)
R^2	0.154	0.152	0.543	0.541
N		1943		

The numbers in parentheses are t-ratios
*** $P < 0.01$; ** $P < 0.05$; * $P < 0.1$

weights of recyclables and garbage were measured depending on the number of employed garbage collection trucks. Undoubtedly, the data collected for such municipalities was inaccurate. However, the samples from these municipalities could not be excluded because they constituted a certain part of the total samples collected in 1997. In this study, a dummy variable corresponding to the usage of a weighbridge (*chukan keiryo*) was employed as an explanatory variable in the recyclables and garbage regression equations. The estimation results indicated that the existence of a weighbridge had a statistically significant effect on the amounts of both garbage and recyclables emission. Due to the difference in the weight measurement method employed, the gauged amount is likely to be affected to a certain degree.

Most importantly, the price of bags and tags had a negative effect on garbage emission. This result is consistent with the economic intuition. Furthermore, the dummy variable for the collection of PET bottles, which indicated municipal implementation of PET bottle collection, had a negative effect on garbage emission. Subsequently, the coefficients for the price of bags and tags with regard to the dummy variable for the collection of PET bottles were estimated positively in the recyclables equation. The coefficient of the PET bottles collection dummy was estimated negatively in the garbage equation. Policy implications of these results are discussed in the following section. The glass collection dummy, which indicated municipal implementation of glass bottle collection, was estimated in positive sign in the recyclables equation. This result implies that glass bottles collection evidently increases the amount of recyclables.

There is a possibility that recyclables Eq. 1 may suffer from multicollinearity because the dummy variables for collection (d_i) may have been highly correlated with the product term between the dummy and unit-based price ($d_i \cdot p_i$). However, it appears that multicollinearity in the recyclables equation did not occur because all the variance inflation factors (VIF)[11] for the concerned variables were less than 10 as shown in Table 4.

Table 4. Results of variance inflation factors (VIF)

Explanatory variables	VIF
Glass	1.691
Glass · Price	3.297
PET bottles	1.861
PET bottles · Price	1.832
Cans	1.062
Cans· Price	3.353
Paper containers	1.817
Paper containers · Price	2.594
N	1943

[11] The variance inflation factors (VIF) is an index that indicates the severity of multicollinearity. See Greene (2000), Chap. 6.

The coefficients for the inverse Mill's ratio, ρ_1 and ρ_2, were estimated significantly in both the recyclables and garbage equations. These results suggest that the covariance of error terms in the recyclable and garbage equations (i.e. σ_{21} and σ_{31}) were significantly different from zero. Hence, it can be stated that a sample selection bias might have occurred if Heckman's two-step estimation had not been employed.

5 Garbage reduction and recycling promotion

The estimation results of the selected model suggest that a 10-yen increase in the price of bags and tags reduces the garbage weight by 28.04 g per capita per day. On the other hand, a 10-yen increase in the price of bags and tags increases the quantity of the PET bottles collected by 5.37 g per capita per day when its collection is implemented. This quantity is regarded as a recycling effect under garbage pricing and PET bottles collection. This result suggests that the unit-based garbage pricing facilitates recycling of PET bottles by citizens when collection is introduced in a municipality. The estimation results suggest that the adoption of garbage pricing is effective to promote PET bottle collection.

However, these results imply that the reduced amount of garbage due to the price of bags and tags was considerably larger than the recycling effects with regard to weight. Therefore, it can be assumed that the amount of garbage reduction comprises not only the citizen's effort toward garbage reducing and recycling but also self-disposal, such as composting and illegal dumping.[12] Considering these effects caused by unit-based garbage pricing is of importance. Tanaka et al. (1996) suggested that an increase in self-disposal would contribute to waste reduction under garbage pricing. On the other hand, Yamakawa et al. (2002) suggested that garbage pricing did not necessarily increase illegal dumping. They showed that some municipalities had been negatively affected by illegal dumping even before the introduction of garbage pricing. Furthermore, they demonstrated that the level of price for garbage and the seriousness of illegal dumping were not correlated. However, determining the actual amount resulting from such behavior is difficult. Accordingly, this study did not examine the extent of composting and illegal dumping. Further investigation on this issue is required in a future study.

Subsequently, the effect of the collection of the four recyclables was investigated. Only the coefficient of the dummy variable for PET bottles in the garbage equation was estimated significantly, while the introduction of the collection of other recyclables is not equally effective. This suggests that the implementation of the collection of PET bottles reduces the amount of garbage emission. The reduced amount caused by collection of PET bottles was estimated at 34.98 g per

[12] According to the Ministry of Environment, Japan (2007), "reducing" implies making careful decisions regarding the use of things in order to reduce the amount of waste generated. Hence, self-disposal such as composting and illegal dumping is not included in reducing. In this study, we have employed the abovementioned definition of reducing.

capita per day. This quantity represents the recycling effect of implementing the collection of PET bottles.

However, the average Japanese consumption of PET bottles in 1997 was only about 5 g per capita per day according to the Council for PET Bottle Recycling (2007). Compared with the amount of average consumption of PET bottles, the reduced (34.98 g per capita per day) is much larger. Therefore, the reduced amount is likely to include other kinds of waste accompanied with PET bottle collection. It is possible that the municipal decision for implementation of PET bottle collection stimulates environmental awareness of the residents. Consequently, reducing and recycling for every kind of waste would be encouraged by the PET bottle collection, and then garbage would be reduced more than the recycled amount of PET bottles. However, this study could not recognize what kind of waste other than PET bottles was included in the reduced amount.

Thus, the estimation results for the recyclables and garbage equations suggest that a mixed policy that consists of garbage pricing and the collection of PET bottles facilitates garbage reduction and recycling by encouraging citizens to sort recyclables from waste.

6 Conclusions

This article has clarified the effects of garbage pricing and the introduction of recyclables collection on Japanese waste emissions, using the municipality data pertaining to waste management policies and socio-economic factors. In the estimation process, we first carried out Heckman's two-step estimation. Subsequently, the factors that affected garbage emission and recyclables collection were investigated using the SUR in order to account for the correlation between the error terms of the garbage equation and the recyclables equation.

The estimation results for the garbage equation suggest that garbage pricing and the municipalities' decision to collect and recycle PET bottles leads to garbage reduction. The results for the recyclables equation indicate that the higher the price of bags and tags, the larger is the amount of recyclables collected when PET bottle collection is implemented. Thus, this article examined the effects of the collection of containers and packaging recyclables as well as those of municipal garbage pricing on Japanese citizens' behavior with regard to garbage and recyclables emission. The findings suggest that a mixed policy that is composed of garbage pricing and the collection of PET bottles facilitates garbage reduction and recycling by encouraging citizens to recycle. Furthermore, a comparison between the coefficients for the price of bags and tags in the garbage and recyclables equations implies that garbage pricing may cause both composting and illegal dumping; this is because the coefficient for the price of bags and tags in the garbage equation is considerably larger than that in the recyclables equation. However, this study could not definitely identify which factors contribute to the difference. Further investigation on the difference is left to a future study.

In this study, the data for recyclables is the sum of the collected amounts for the four containers and packaging recyclable materials. Future studies should investigate the change in each amount of them caused by garbage pricing independently. Such an investigation would require a considerably more advanced econometric technique because a complicated sample selection structure would be generated for such an analysis. On the other hand, Kinnaman and Fullerton (2000) treated unit-based price as an endogenous variable. This is because there is a possibility that the price level may be affected by other waste management factors; that is, the amount of garbage emission and recyclables collection. This relationship perhaps also plays a significant role in the decisions made by Japanese municipalities with regard to pricing of bags and tags, because the Japanese policymakers in each municipality may consider the amount of garbage emission and recyclables collection when determining the price. The treatment of the price of bags and tags in the garbage and recyclables equations should be addressed in future research.

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Appendix

The detail of econometric assumption is shown in this Appendix.

A Sample selection

Defining C_i^* as a latent variable for C_i, we have the following equation.

$$C_i^* = z_i'\alpha + \varepsilon_{0i}$$

Detail of the indicator function in the probit model is expressed as follows.

$$C_i = \begin{cases} 1 & \text{if} \quad C_i^* = z_i'\alpha + \varepsilon_{0i} > 0 \\ 0 & \text{if} \quad C_i^* = z_i'\alpha + \varepsilon_{0i} \leq 0 \end{cases}$$

The probit model gives the following inverse Mill's ratio, λ_i.

$$\lambda_i = \frac{\phi(z_i'\hat{\alpha})}{\Phi(z_i'\hat{\alpha})}$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ are the probability density function and cumulative distribution function of the normal distribution, respectively. $\hat{\alpha}$ is the predicted value of α.

The amount of recyclables collected can be observed only when municipalities collect it. Therefore, the following relation is established.

$$R_i = \begin{cases} R_i & \text{if} \quad C_i = 1 \\ \text{unobservable} & \text{if} \quad C_i = 0 \end{cases}$$

This relation makes sample selection a problem.

B Error terms

Error terms ε_{0i}, ε_{1i}, ε_{2i} are assumed to have a following multivariate normal distribution.

$$\begin{bmatrix} \varepsilon_{0i} \\ \varepsilon_{1i} \\ \varepsilon_{2i} \end{bmatrix} \sim N(0,\Sigma), \quad \Sigma = \begin{pmatrix} 1 & \sigma_{21} & \sigma_{31} \\ \sigma_{21} & \sigma_{22} & \sigma_{32} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{pmatrix}$$

This study assumes that σ_{21}, σ_{31}, and σ_{32} are not equal to zero. This assumption requires introduction of the sample selection model and seemingly unrelated regression (SUR).