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Effective Policy Package on Household Garbage and Recycling

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1. Introduction

An increasing number of local governments in Japan have begun charging their residents for garbage collection. The share of cities that implement a user-fee program for garbage collection increased from 20% in 2000 to roughly 40% in 2004 (Yamakawa and Yano, 2008). In Japan, there are basically two types of user-fee programs: the unit-based pricing program and the flat-fee program. The unit-based pricing program, which is widely used in many municipalities, requires each household to purchase a special bag or sticker for each unit of garbage it presents for collection. The flat-fee program, now used in a minority of municipalities, imposes on each household a fixed fee per family regardless of the quantity of garbage.

Waste management is a responsibility of the local government in Japan. Municipalities are obliged to collect four types of waste separately: (1) burnable garbage, such as food scraps; (2) noncombustible garbage, such as glass or fluorescent lights; (3) recyclable material, including cans, bottles, plastic pet bottles, magazines, newspapers; and (4) bulky waste. However, the classification of burnable and noncombustible garbage differs by municipality. For instance, some municipalities classify plastic as burnable garbage, whereas others classify it as noncombustible garbage. Statistics of the Ministry of the Environment in Japan classify burnable garbage and noncombustible garbage as general waste.

The quantity of household garbage has not greatly decreased between 2000 and 2004. The quantity of household garbage per capita dumped in 2004 was 1.09 kg a year (Ministry of the Environment, 2004). That was a decrease of only 3.5% from 1.13 kg in 2000. However, the recycling rate rose from 14.3% in 2000 to 17.6% in 2004. Moreover, Japan has a particular problem—a shortage of dump-sites. Since Japan is small, it is difficult to secure governmental permission to build a dump-site. In 2004, Japan's existing dump-sites had an average remaining life of 13.2 years. Therefore, it is necessary for the Japanese to reduce the quantity of garbage and to promote recycling immediately. It is also the reason why municipalities are considering charging for collection of household garbage and recyclable material.

There must be other economic approaches that are effective for reducing household garbage and promoting recycling than charging for municipal garbage collection and disposal. This paper employs municipality-level data in Japan to suggest a more effective policy for reducing household garbage and promoting recycling. It is an important contribution to clarify a more effective policy package to reduce household garbage and promote collection of recyclable materials for municipalities in Japan.

Our paper makes three main contributions. First, we collect original data from a significantly large cross-section of Japanese municipalities, and we estimate the price elasticity of garbage demand in Japan. Evaluated at the mean price, the price elasticity is −0.024 for municipalities with price data calculable in our sample, and −0.215 for municipalities that implement a unit-pricing program. Second, while other studies estimate the demand for garbage collection or for recycling collection, we estimate both with seemingly unrelated regression (SUR) because households dispose garbage and recyclable materials simultaneously. Third, we suggest an effective package of municipal policies to reduce household garbage and promote recycling.

This paper is organized as follows. Section 2 describes previous literature concerning reducing household garbage and recyclable materials. Section 3 discusses our empirical method and data. Section 4 estimates the effect of municipal policies on garbage and recycling employing cross-sectional data of Japan using SUR. Section 5 concludes the paper.

2. The previous literature

There are several empirical studies about policies to reduce waste and encourage recycling.[1] Many researchers have especially discussed the effect of user-fee programs for garbage collection and disposal service. There are two streams of literature that estimate the impact of implementing unit-based pricing programs. The first uses cross-sectional data from municipalities (Wertz, 1976; Jenkins, 1993; Miranda et al., 1994; Strathman et al., 1995; Callan and Thomas, 1997; Podolsky and Spiegel, 1998; Van Houtven and Morris, 1999; Kinnaman and Fullerton, 2000; Dijkgraaf and Gradus; 2004). The second uses household survey data (Hong et al. 1993; Reschovsky and Stone, 1994; Fullerton and Kinnaman, 1996; Van Houtven and Morris, 1999; Hong, 1999; Hong and Adams, 1999; Linderhof et al., 2001; Jenkins et al., 2003).

In Japan, many empirical studies analyze municipal policies, which effectively reduce the quantity of household garbage (Maruo et al., 1997; Sasao, 2000; Usui, 2003; Nakamura, 2004; Nakamura et al., 2007).[2] However, because price data per garbage bag are not provided publicly in Japan, Maruo et al. (1997), Sasao (2000) and Nakamura (2004) analyze the effect of the pricing program on municipal garbage collection and disposal service using dummy variables (=1 where a pricing program is implemented, and =0 otherwise). They show that the unit-pricing type of user-fee program is effective in reducing household garbage, and that flat-fee program is ineffective.[3]

However, using dummy variables to represent user fees as a factor in reducing the quantity of garbage presents two problems: it becomes impossible to consider variation of price per garbage bag among municipalities, and it merely verifies the average effect of a user-fee program on garbage reduction. Given this situation, we cannot analyze the relation between the setting of the price and the quantity of garbage. In addition, estimates of the effect of user-fee programs on the quantity of garbage are insufficient.

Recently, several researchers have collected original price data for user-fee

[1] Kinnaman and Fullerton (1999) and Kinnaman (2006) give an overview of the empirical studies.
[2] Yamakawa and Ueta (1996, 2001) provide an overview of the Japanese literature.
[3] The marginal cost that households faced in the flat-fee pricing program is zero. It is a program design that might not incentivize reducing the quantity of garbage per household.

programs and estimated price elasticity of garbage demand. Usui (2003) interviewed 611 municipalities and collected the price of garbage bag. Results using cross-sectional data for municipalities showed that the price elasticity of municipal garbage collection and disposal is −0.082. Nakamura et al. (2007) collected, via e-mail, original price data for garbage bags. They estimate the price elasticity equal to −0.026 evaluated at the average price per garbage bag.[4]

Estimation of price elasticity in Japan is in the early stage of research, as mentioned above. We focus not only on the user-fee program in municipal solid waste management policy but also on economic instruments such as the number of segregations, frequency of collection service, collection system, etc. The purpose of this paper is to indicate direction for an effective policy to reduce garbage and promote recycling. While other studies estimate the demand for garbage collection or for recycling collection respectively, we estimate both with SUR as households dispose of garbage and recyclable materials simultaneously. This paper contributes to the empirical literature estimating the effects of municipal policies designed to reduce household garbage and promote recycling.

3. The model

We estimate the following model to show an effective policy package for municipalities to reduce garbage and collect more recyclable materials (Model 1):

$$\log G_i = \alpha_{10} + X_i\alpha_{11} + \alpha_{12}S_i + F_i\alpha_{13} + C_i\alpha_{14} + I_i\alpha_{15} + u_{1i} \tag{1}$$

[4] The difference in price elasticity estimated in these two articles arises from differences in the dependent variable used. Nakamura et al. (2007) use the quantity of household garbage as a dependent variable, which excludes bulky waste. Usui (2003) uses the total quantity of household garbage as a dependent variable, which includes bulky waste. But households' decision-making for disposing of general waste and bulky waste must be different.

$$\log R_i = \beta_{10} + X_i\beta_{11} + \beta_{12}S_i + F_i\beta_{13} + C_i\beta_{14} + I_i\beta_{15} + \varepsilon_{1i} \quad , \tag{2}$$

$$where \;\; F_i = \begin{bmatrix} F_i^G & F_i^R \end{bmatrix},\; C_i = \begin{bmatrix} C_{si}^G & C_{hi}^G & C_{ki}^G \\ C_{si}^R & C_{hi}^R & C_{ki}^R \end{bmatrix},\; I_i = \begin{bmatrix} I_{fi}^G & I_{vi}^G \\ I_{fi}^R & I_{vi}^R \end{bmatrix},$$

where G_i and R_i are the per capita weight of garbage and recycling for municipality i those were exhausted by household for the municipality's collection service, respectively. Both are converted into logarithms. X_i is a vector of independent variables. The econometric model controlled for per capita income, household size, gender ratio, floor space per capita, population density, and rate of daytime population to nighttime population. S_i is the number of segregations of garbage. F_i is the vector of frequency of collection of garbage and recyclable materials. C_i is the vector of dummy variables, which indicate the collection system of garbage and recyclable materials, respectively. The superscript s denotes that garbage and recyclable materials are collected at the limited number of places selected by municipalities.[5] The superscript h denotes that garbage and recyclable materials are collected individually in front of a resident's house. The superscript k denotes that both types of these collection systems are adopted in one municipality. I_i also includes vectors of dummy variables that indicate the presence of user-fee pricing programs for garbage and recyclable materials, respectively. The subscript f denotes that the user fee is fixed regardless of the quantity of garbage (flat fee); and the subscript v denotes that the user fee is variable according to the number of garbage bags (unit-pricing).

In addition to Model 1, we estimate the following model, which includes the price per garbage bag, to calculate the price elasticity of demand (Model 2):

$$\log G_i = \alpha_{20} + X_i\alpha_{21} + \alpha_{22}S_i + F_i\alpha_{23} + C_i\alpha_{24} + I_i\alpha_{15} + \alpha_{26}\,price_i + u_{2i} \tag{3}$$

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5 This type of collection system is called "station" in Japan.

$$\log R_i = \beta_{20} + X_i\beta_{21} + \beta_{22}S_i + F_i\beta_{23} + C_i\beta_{24} + I_i\beta_{25} + \varepsilon_{1i} \quad , \tag{4}$$

$$where \quad F_i = \begin{bmatrix} F_i^G & F_i^R \end{bmatrix}, \; C_i = \begin{bmatrix} C_{si}^G & C_{hi}^G & C_{ki}^G \\ C_{si}^R & C_{hi}^R & C_{ki}^R \end{bmatrix}, \; I_i = \begin{bmatrix} I_{fi}^G & I_{vi}^G \\ I_{fi}^R & I_{vi}^R \end{bmatrix},$$

where $price_i$ denotes the price per garbage bag, which we originally collected from each prefecture.[6] We calculate price per 10-liter garbage bag from our collected data in municipalities that implement a unit-pricing program, and set zero in the municipality that implements a flat fee or no fee. The marginal price, which is imposed on the resident, is positive in municipalities that implement a unit-pricing program. The marginal price is zero in municipalities that implement a flat fee or no fee. Data used in the analysis are cross-sectional data for 2004, and the number of observations is 2,070. The number of observations in Model 2 is 1,633, which is fewer than Model 1 because the price data are missing.

It is possible that a part not explained by the explanatory variables is included in the error term and that the correlation is caused in the error term of each function, because the households' decisions to dispose of garbage and recyclable materials occur simultaneously. We then estimate both Eq.(1) and Eq.(2), and Eq.(3) and Eq.(4), with SUR, a procedure advocated by Zellner (1962) to deal with this problem.

Definitions of variables and data sources are shown in Table 1, and descriptive statistics of these variables are shown in Table 2.

Table 2 shows considerable variation among municipalities. Garbage averages 236.3 kg per person per year. Recycling averages only 39.8 kg per person per year. Number of segregations ranges from 2 to 26, and it averages 11. Frequency of collection service for household garbage averages two or three times per week, and frequency of collection service for recyclable materials averages only once every two weeks. About 90% of municipalities have adopted the station collection system. Less than half of

[6] We e-mailed questionnaires to all (47) prefectures in Japan and received 19 replies.

municipalities charge for garbage collection. About 29.8% of municipalities adopt the unit-pricing user-fee system, and 14.4% adopts the unit-charging system. On the other hand, collection of recyclable materials is free in most municipalities. Although we have a sample size of 2,070 from publicly available data, we gathered data from 1,633 municipalities by our request. We eliminate the remaining 437 municipalities from the regressions of Model 2, which reduces our sample size to 1,633. The price ranges from zero to ¥25.7 per 10-liter garbage bag, and it averages ¥1.127 per 10-liter bag.

4. Estimation results

The estimation results using SUR are shown in Table 3. The null hypothesis that the correlation of the error term is zero is rejected from the result of the Breusch–Pagan test at the 1% significance level. Let us first examine the results of Model 1.

4.1 Other control variables

The coefficient on the logarithm of per capita income is positive for the quantity of household garbage and recyclable materials and significant at the 1% level. Households with high incomes not only have more waste material, but they also face a high opportunity cost for time spent dumping. Therefore, high-income households dispose of more garbage and recyclable materials. A 1% increase in per capita income increases the quantity of the household garbage by 0.38% and recyclable material by 0.46%.[7] The income elasticity of recyclable materials is higher than that of garbage because many heavy-weight items are included in recyclable waste: newspaper, magazines, waste cans, empty bottles, etc.

Household size has a negative relationship to the quantity of household garbage

[7] Others have estimated income elasticity to be 0.279 and 0.272 (Wertz, 1976), 0.41 (Jenkins, 1993), 0.57 (Podolsky and Spiegel, 1998), and 0.262 (Kinnaman and Fullerton, 2000).

and recyclable materials and is significant at the 1% level: a one-person increase in household size decreases the quantity of garbage by 9.2% and recyclable material by 34.6%.[8] The reason for this result is that families share the use and consumption of many goods. Therefore, the impact on quantity of recyclable materials is larger than for garbage because food packaging, newspapers, and so on that are taken to the municipal collection service for recycling are items consumed by many family members.

The coefficient on the gender ratio (male/female) is negative and significant at 1% level only in the Eq.(1) and is not significant in Eq.(2). If the ratio of male to female increases by 1%, the quantity of household garbage decreases by 0.5%. This result arises from the difference in lifestyle between men and women in Japan. Japanese men dine out more often than women and generate less waste at home. In addition, the general cycle time from purchase to abandonment of clothes is slower among men relative to women.

The floor space per capita has different effects on the quantity of household garbage and recyclable material. The coefficient on floor space per capita of Eq.(1) is negative and that of Eq.(2) is positive and significant at the 5% level. A one square meter increase in floor space per capita decreases the quantity of household garbage by 0.4% and increases the quantity of recyclable material by 0.8%. The reason for this result is that it is easier for households living in roomy homes to store unnecessary wastes, such as clothing that is purchased but never worn, and it is easier to separate and store recyclable materials because households can maintain spaces for trash boxes.

The coefficients on population density and the density-squared are significant. Population density has a positive effect on the quantity of household garbage and a negative effect on the quantity of recyclable materials. In Eq.(1), the coefficient on density is positive. Although households in rural areas can burn or compost their waste in their backyard, urban households must use the municipality's garbage collection and

[8] Jenkins (1993), Podolsky and Spiegel (1998), Dijkgraaf and Gradus (2004) find that an increase in the size of households decreases the per capita quantity of garbage disposed.

disposal service. The square term is negative; we find the marginal quantity of garbage decreasing with population density.

On the other hand, in Eq.(2) the coefficient on population density is negative and the square term is positive. Many supermarkets set out collection boxes for people to deposit paper, food packaging trays, glass bottles, metal cans, dry cell batteries, and so forth in areas where population density is very high. In addition, homeless people sometimes collect recyclable waste and sell it to collection traders before it is collected by the municipality. In both instances, recyclable waste is collected without depending on the service provided by the municipality in these areas.

The coefficient on the ratio of daytime population to nighttime population is positive and significant only in regard to the quantity of household garbage. The business and commercial garbage is charged in Japan. More than half of Japan's municipalities provide garbage collection service without charge, as shown in Table 2. There is a possibility that business and commercial garbage is mingled with household garbage in areas where daytime population is high.

4.2 Policy variables

We now discuss the results of our study for municipal waste management policy.

The coefficient on the number of segregation shows a negative impact on the quantity of household garbage and a positive impact on the quantity of recyclable materials.[9] The 1.4% decrease in the weight of garbage and the 6.1% effect on collection of recyclable waste can be expected by increasing one kind of number of segregation. This estimated result implies that increasing the number of segregation of waste is one of the effective policies for reducing household garbage and collecting recyclable materials.

The coefficient on frequency of garbage collection service per week is positive for

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9 Duggal et al. (1991) also find that increases in the number of items increases the quantity of recycled glass.

the quantity of household garbage and negative that the quantity of recyclable materials and significant at the 1% level. On the other hand, the coefficient on frequency of recycling collection service per week is negative for the quantity of household garbage and positive to that of recyclable materials.[10] These estimated results imply that decreasing the frequency of garbage collection and increasing the frequency of recycling collection also are effective policies for reducing garbage and collecting recyclable materials. If the costs of collecting garbage and collecting recyclable materials are the same, our estimates show that the municipality should shift from the collection of garbage to collection of recyclable wastes.

Variations among collection systems have little impact on the quantity of household garbage and recyclable materials. The base group of collection system dummy variables is “station” system. We believe the coefficient on individual household collection is significantly positive because it is easy for households to dispose of garbage and recyclable materials. However, the coefficient on the combination of station collection and household collection is positive for the quantity of household garbage, and the coefficient on “others” is negative for the quantity of recyclable material. We can neither explain these results nor draw conclusions concerning the type of collection system because there is narrow variation among collection systems, as shown in Table 2.

The implementation of user-fee pricing systems for household garbage of flat fee and unit-pricing type has a negative effect on the quantity of household garbage and is significant at the 1% level. If the municipality employs a flat-fee program, the quantity of household garbage declines by −14.8% (= exp(−0.160) −1) relative to municipalities that do not implemented user-fee programs. If the municipality employs a unit-pricing program, the quantity of household garbage declines −10.3% (= exp(−0.108) −1) relative to municipalities that do not implement a user-fee system. Ordinarily, because

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[10] Duggal et al. (1991) estimate that the quantity of recycled glass increases with the frequency of collection.

unit-pricing programs provide better marginal incentives, we would predict that the quantity of household garbage collected by unit-pricing programs is less than that by flat-fee programs. Unfortunately, however, it is not known exactly why, and discovering why is a task for the future. We cannot obtain statistically significant results in the implementation of user-fee program for recyclable materials.

4.3 The price elasticity of demand for garbage

Next, we discuss the estimated results of Model 2. Our estimates of Model 2 are similar to Model 1. We find that the estimated coefficients on these variables are robust. Therefore, we describe only findings that pertain to the price per bag.

The coefficient on the price per bag is negative for the quantity of household garbage and significant at the 1% level. By these estimates, the change in price per bag of ¥1 would reduce weight of garbage by 2.1%. The price elasticity is −0.024 (= −0.021 × 1.127), evaluated at the point of the mean price (¥1.127/10 liter), because the coefficient on the price per bag implies semi-elasticity. The price elasticity at this point is very low because the average price is very low.[11] Most municipalities in our sample had not implemented a user-fee program and thus charged a price of zero. Among municipalities with unit-pricing user-fee programs, the average price charged was ¥10.235. Evaluated at this point, the price elasticity is −0.215 (= −0.021 × 10.235). This calculation is perhaps the one that is most appropriate to compare with price elasticity estimates provided in the previous literature.[12]

5. Conclusion

[11] Kinnaman and Fullerton (2000) estimates the price elasticity at the mean price is −0.034.

[12] Others have estimated price elasticity to be −0.15 (Wertz, 1976), −0.12 (Jenkins, 1993), −0.39 (Podolsky and Spiegel, 1998), −0.15 (VanHoutven and Morris, 1999), −0.28 (Kinnaman and Fullerton, 2000), −0.08 (Usui, 2003), −0.43 (Dijkgraaf and Gradus, 2004).

This paper estimates the implications of municipal policy on reducing household garbage and promoting recycling in Japan. We collected original data from a significantly large cross-section of Japanese municipalities, and we estimated the price elasticity of garbage, which is −0.024 evaluated at the average price per bag (¥1.13/10 liter) for municipalities with price data calculable in our sample, and −0.215 at the average price (¥10.24/10 liter) for municipalities that implement a unit-pricing program. We employ SUR because households dispose of garbage and recyclable materials simultaneously.

Our results show that a municipality can expect to reduce the quantity of household garbage and to promote recycling by implementing the following policies. (1) Increase the number of segregations. (2) Decrease the frequency of collection service for household garbage and increase frequency of collection for recyclable material. (3) Implement a unit-pricing program for collecting household garbage and collect recyclable material free of charge.

However, we cannot determine the optimal municipal policy for reducing household garbage and promoting recycling. We only indicate a direction for effective policy. Japanese municipalities are increasingly implementing user-fee programs to help reduce household garbage. The advisability of these policies depends on the circumstances specific to municipalities, such as number and condition of garbage disposal facilities, the extent of illegal dumping, their fiscal condition, etc.

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Table 1 Definitions of variables

Variables	Unit	Definitions of Variables	Data source
Household garbage per capita	kg	Weight of household garbage / Number of population	Ministry of the Environment, *Survey on Disposal of General Waste*
Recyclable material per capita	kg	Weight of recyclable materials / Number of population	Ministry of the Environment, *Survey on Disposal of General Waste*
Income per capita	million yen	Income / Number of population	Income: Ministry of International Affairs and Communications, *Survey of Taxation of Cities, Towns and Villages Tax*
			Population: Ministry of International Affairs and Communications, *Population Census*
Family size	person	Number of population / Number of households	Ministry of International Affairs and Communications, *Population Census*
Gender ratio	%	(Population of man / Population of woman) * 100	Ministry of International Affairs and Communications, *Population Census*
Floor space per capita	m^2	Floor spaces / Population	Ministry of International Affairs and Communications, *Population Census*
Population density	1,000 people / km^2	Population / Area	Ministry of International Affairs and Communications, *Population Census*
Rate of daytime population to nighttime population	%	(Daytime population / Population) * 100%	Ministry of International Affairs and Communications, *Population Census*
Number of segregation	items	burnable, unburnable, recycable such as paper, petbottle and magazine so on	Ministry of the Environment, *Survey on Disposal of General Waste*
Frequency of collection service	times per week	Frequency of the collcetion service a month / 4 weeks	Ministry of the Environment, *Survey on Disposal of General Waste*
Collection system	dummy	Dummy variables as follows:	Ministry of the Environment, *Survey on Disposal of General Waste*
Station		Station which municipality decided=1, others=0.	
Individual		In front of house individually=1, others=0.	
Combination		Conbination of station and individual=1, others=0.	
Others			
Implementation of user fee system	dummy	Dummy variables as follows:	Ministry of the Environment, *Survey on Disposal of General Waste*
Unit-pricing		User fee is variable per garbage bag=1, others=0.	
Flat fee		User fee is fixed=1, others=0.	
Price per garbage bag	yen / 10 liter	The price per garbage bag.	Originally collected

Table 2 Descriptive statistics

Variables	Unit	All sample (Obs.=2070)				Sample including variable of price per bag (Obs.=1633)			
		Mean	Std.Dev.	Min.	Max.	Mean	Std.Dev.	Min.	Max.
Dependent variables									
Household garbage per capita	kg	236.338	87.329	15.456	1129.432	242.064	85.959	15.456	1129.432
Recyclable material per capita	kg	39.759	27.285	0.223	325.473	39.805	26.804	0.223	325.473
Controll variables									
Income per capita	1 million yen	1.079	0.279	0.409	2.599	1.095	0.295	0.409	2.599
Family size	person	3.071	0.456	1.701	4.567	3.079	0.457	1.701	4.567
Gender ratio (Male to female rate)	%	93.994	6.561	65.796	180.025	94.295	6.829	65.796	180.025
Floor space per capita	m^2	39.096	5.722	23.212	63.784	38.943	5.882	23.212	63.784
Population density	1,000 people / km^2	0.641	1.381	0.002	13.371	0.732	1.506	0.002	13.371
Rate of daytime population to nighttime population	%	93.578	11.159	60.915	289.923	93.577	11.658	61.051	289.923
Policy variables									
Number of segregation	items	10.930	4.559	2.000	26.000	11.070	4.607	2.000	26.000
Frequency of collection service	times per week								
For household garbage		2.816	0.893	0.000	11.500	2.825	0.847	0.000	8.000
For recyclable material		0.521	0.296	0.000	1.750	0.518	0.292	0.000	1.750
Collection system	dummy								
[Household garbage] Station		0.876	0.330	0.000	1.000	0.888	0.316	0.000	1.000
[Household garbage] Individual		0.052	0.221	0.000	1.000	0.045	0.207	0.000	1.000
[Household garbage] Combination		0.069	0.254	0.000	1.000	0.063	0.243	0.000	1.000
[Household garbage] Others		0.003	0.058	0.000	1.000	0.004	0.065	0.000	1.000
[Recyclable material] Station		0.897	0.305	0.000	1.000	0.903	0.296	0.000	1.000
[Recyclable material] Individual		0.043	0.203	0.000	1.000	0.037	0.188	0.000	1.000
[Recyclable material] Combination		0.050	0.218	0.000	1.000	0.048	0.215	0.000	1.000
[Recyclable material] Others		0.010	0.100	0.000	1.000	0.012	0.107	0.000	1.000
Implementation of user fee program	dummy								
[Household garbage] Unit-pricing		0.298	0.457	0.000	1.000	0.110	0.313	0.000	1.000
[Household garbage] Flat fee		0.144	0.351	0.000	1.000	0.179	0.384	0.000	1.000
[Recyclable material] Unit-pricing		0.100	0.299	0.000	1.000	0.040	0.196	0.000	1.000
[Recyclable material] Flat fee		0.060	0.238	0.000	1.000	0.074	0.262	0.000	1.000
Price per garbage bag	yen / 10 liter					1.128	3.566	0.000	25.741

Table 3　Estimation results of SUR

		Model 1						Model 2					
		Household garbage per capita (logarithm) Eq.(1)			Recyclable material per capita (logarithm) Eq.(2)			Household garbage per capita (logarithm) Eq.(3)			Recyclable material per capita (logarithm) Eq.(4)		
Controll variables													
Income per capita	logarithm	0.383	(0.037)	***	0.458	(0.080)	***	0.398	(0.041)	***	0.438	(0.088)	***
Family size	person	-0.092	(0.018)	***	-0.346	(0.038)	***	-0.086	(0.019)	***	-0.309	(0.042)	***
Gender ratio (Male/Female)	percent	-0.005	(0.001)	***	0.001	(0.003)		-0.005	(0.001)	***	-0.001	(0.003)	
Floor space per capita	m^2	-0.004	(0.002)	**	0.008	(0.004)	**	-0.004	(0.002)	**	0.004	(0.004)	
Population density	1,000 person per km^2	0.087	(0.017)	***	-0.081	(0.036)	**	0.064	(0.018)	***	-0.064	(0.039)	*
Square of population density		-0.010	(0.002)	***	0.008	(0.004)	**	-0.008	(0.002)	***	0.007	(0.004)	*
Rate of daytime population to nighttime population	%	0.006	(0.001)	***	-0.002	(0.002)		0.005	(0.001)	***	-0.003	(0.002)	*
Policy variables													
Number of segregation	items	-0.014	(0.002)	***	0.061	(0.003)	***	-0.016	(0.002)	***	0.057	(0.004)	***
Frequency of collection service	times per week												
For household garbage		0.068	(0.009)	***	-0.093	(0.019)	***	0.070	(0.010)	***	-0.118	(0.022)	***
For recyclable material		-0.063	(0.027)	**	0.419	(0.059)	***	-0.021	(0.031)		0.353	(0.067)	***
Collection system	dummy												
[Household garbage] Individual		0.106	(0.074)		-0.031	(0.159)		0.061	(0.085)		0.024	(0.184)	
[Household garbage] Combination		0.158	(0.050)	***	0.034	(0.106)		0.141	(0.059)	***	0.010	(0.129)	
[Household garbage] Others		-0.130	(0.126)		0.187	(0.271)		-0.112	(0.124)		0.192	(0.270)	
[Recyclable material] Individual		0.056	(0.081)		0.158	(0.174)		0.107	(0.093)		0.038	(0.202)	
[Recyclable material] Combination		-0.077	(0.057)		0.188	(0.123)		-0.035	(0.067)		0.168	(0.147)	
[Recyclable material] Others		0.093	(0.073)		-0.969	(0.156)	***	0.086	(0.075)		-0.992	(0.163)	***
Implementation of user fee program	dummy												
[Household garbage] Unit-pricing		-0.108	(0.019)	***	-0.032	(0.040)		0.130	(0.063)	**	0.018	(0.067)	
[Household garbage] Flat fee		-0.160	(0.026)	***	0.017	(0.056)		-0.167	(0.026)	***	0.020	(0.057)	
[Recyclable material] Unit-pricing		-0.098	(0.028)	***	-0.060	(0.060)		-0.062	(0.049)		-0.224	(0.106)	**
[Recyclable material] Flat fee		0.028	(0.038)		-0.017	(0.081)		0.030	(0.038)		-0.012	(0.083)	
Price per garbage bag								-0.021	(0.005)	***			
Constant		5.787	(0.174)	***	3.759	(0.374)	***	5.780	(0.188)	***	4.141	(0.410)	***
R-squared		0.292			0.224			0.301			0.213		
Breusch-Pagan test		53.679	***					36.539	***				
Number of observations		2,070						1,633					

Note: Standard errors are in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% level, respectively.

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