ECOLOGICAL ECONOMICS 66 (2008) 282–288

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ANALYSIS

Estimating the effect of unit-based pricing in the presence of sample selection bias under Japanese Recycling Law

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ARTICLE INFO

Article history:
Received 23 September 2006
Received in revised form 31 August 2007
Accepted 11 September 2007
Available online 26 October 2007

Keywords:
Solid waste
Unit-based pricing
Recycling
Sample selection bias

JEL Classification:
C24; R53

ABSTRACT

In Japan the Containers and Packaging Recycling Law requires the collection of recyclable packaging and containers. In particular, municipalities are required to collect and store the containers and packaging that households have separated from solid waste. However, the law has non-binding standards, and some municipalities do not provide collection services for these recyclables. When estimating the substitution effect of unit-based pricing, i.e. the substitution of recyclables for solid waste, missing data for those municipalities that do not provide a collection service will lead to a truncated sample and, therefore, a sample selection bias in the estimators. We use a Type 2 Tobit model to correct a bias which arises because of missing data. This model provides a consistent estimator, and shows that a higher price for bags and tags increases recycling by households under the unit-based pricing systems introduced by municipalities.

1. Introduction

In Japan, several recycling laws have been enforced since the 1990s. Most importantly, the introduction of the Containers and Packaging Recycling Law began in 1997. This legislation encourages municipalities to support the collection of recyclable materials separated by households. In the beginning of 1997, however, few municipalities had implemented collection programs for recyclables as outlined by the law.[1]

On the other hand, unit-based pricing has been adopted by many municipalities. Unit-based pricing creates an economic incentive for households to reduce burnable and non-burnable[2] waste by separating out recyclables. Under unit-based pricing households are required to dispose of solid waste using special bags, or tags, that include a disposal fee in the purchase price. This price is usually set according to whether the bag will be used to dispose of burnable or non-burnable waste. Since there is no disposal fee for recyclable waste, households can save money by separating out recyclables. We refer to this as the substitution effect of unit-based pricing.

There is a large empirical literature on burnable and non-burnable waste generation and the incentive to recycle created by unit-based pricing (Hong and Adams, 1993; Saltzman et al., 1993; Reschovsky and Stone, 1994; Callan and

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[1] At first the legislation specified three types of glass bottles (no color, brown, and other colors), and PET bottles for recycling. Paper and plastic containers were added in 2000.

[2] The words "burnable" waste and "non-burnable" waste classify waste in terms of whether it is directly going to the incinerator or directly to landfill sites in Japanese municipalities.

0921-8009/$ – see front matter
doi:10.1016/j.ecolecon.2007.09.002

Thomas, 1997; Nestor and Podolsky, 1998; Hong and Adams, 1999; Sterner and Bartelings, 1999; Kinnaman and Fullerton, 2000; Jenkins et al., 2003).[3] Reschovsky and Stone (1994) examine the recycling probabilities of households using a sample of micro-data for recyclable materials, but the explanatory variable for unit price is a dummy variable. Kinnaman and Fullerton (2000) estimate demand equations for solid waste and recycling in order to make the unit price and curbside recycling endogenous. However, their recycling data is aggregated. Jenkins et al. (2003) investigate the recycling behavior of households using an ordered probit model with data aggregated by recyclable material.

There is, however, a serious problem that the literature introduced above does not address. A selection bias will occur when using data including some of the regions that do not offer collection services for recyclable materials. The nonexistence of a collection service will cause a sample to be truncated. If the researcher deletes the samples of zero values whose municipalities do not collect the containers, and run OLS on the sample of only the positive observations, a selection bias may arise because the expectation of the error terms are not zero, which violates the assumptions of OLS. The possibility of the arising bias depends on whether or not the data of zero values result in a direct relation to another factor. For example, municipalities do not offer drop-off or curbside collection services due to a reduction in the budget.[4]

Therefore, care should be taken when selecting an area for collecting data on unit-based pricing and the provision of collection services for recyclables.[5] If missing data for municipalities that do not implement a unit-based pricing program or provide a collection service are not accounted for, a sample selection bias may occur in the estimates. This bias should be corrected for by obtaining statistically consistent estimators.[6]

This paper introduces a method for correcting the sample selection bias and estimates the substitution effect of unit-based pricing. Then, we test the wrong OLS estimator, which is used in the previous literatures, and replace it with the correct estimator, i.e., the Type 2 Tobit model in this paper. Next, the effects of unit-based pricing on the collection of recyclable cans, PET bottles, paper containers, and bottles are examined.

The paper proceeds as follows: Section 2 introduces the model; Section 3 gives a description of the data; Section 4 discusses the estimation results, and Section 5 gives some concluding remarks.

2. Model

The model estimated in this paper attempts to identify the effect of unit-based pricing on the recycling of households. However, as discussed above, some municipalities do not operate within the guidelines of recycling legislation. Therefore, the quantities of recycled materials are not observable as a subset of the population. While collection services differ among municipalities, households make a voluntary effort to separate waste into recyclable materials, despite the fact that a collection service may not be available. It is important, therefore, to recognize that the decision to collect recyclables is different for municipalities and households.

When an ordinary least squares estimation method is applied a serious selection bias will arise because the observable sample is missing values as a result of the specific characteristics of the sampled municipalities. With the existence of a selection bias, the statistical condition for a consistent estimator will not be satisfied (Amemiya, 1985). The Type 2 Tobit model has been widely proposed as a correction method in various empirical fields. This paper applies the Type 2 Tobit model using the maximum likelihood method. The Type 2 Tobit model is specified as:

$$y^*_{1i} = \chi'_{1i}\beta_1 + \epsilon_{1i}, \tag{1}$$

$$y^*_{2i} = \chi'_{2i}\beta_2 + \epsilon_{2i}. \tag{2}$$

Eq. (1) is a discrete decision equation about the sample selection, and y^*_{1i} is a latent variable. Eq. (2) is a regression equation for selected samples. A detail of y^*_{2i} will be described later. While y^*_{1i} cannot be observed directly, the sign of the latent variable can be evaluated as either positive or negative if the observable variable y_{1i} takes on a value of 0 or 1. A positive sign occurs if some municipalities adopt the guidelines for the collection of recyclables as provided by recycling legislation. On the other hand, a negative value will arise if municipalities decide not to participate with the legislation, i.e. Though y^*_{1i} is not measured as a monetary unit, the net benefit gained by municipalities by starting the collection of recyclables is positive if the indicator is 1.

$$y_{1i} = \begin{cases} 1 & \text{if } y^*_{1i}>0 \\ 0 & \text{if } y^*_{1i}\leq 0 \end{cases} \tag{3}$$

$$y_{2i} = \begin{cases} y^*_{2i} & \text{if } y_{1i} = 1 \\ \text{unobservable} & \text{if } y_{1i} = 0 \end{cases} \tag{4}$$

Eq. (4) shows that if $y_{1i}=1$, y^*_{2i} can be observed, otherwise it cannot. It is assumed that y^*_{2i} is the amount of recyclables if municipalities receive a positive net benefit by starting the collection of recyclables. The amount of recyclables, y^*_{2i}, is observed only when $y^*_{1i}>0$. Municipalities do not collect recyclables if they do not benefit from recyclables collection,

[3] Miranda et al. (1996) provide a survey of the unit-based pricing literature.

[4] Could we obtain a consistent estimator to apply the normal Tobit model, which includes zero and positive values? The answer is no, because the data of zero values in the estimation equation means that municipalities do not record the above-mentioned data. If the municipalities offer collection services, the data pertaining to the quantities of PET bottles will be recorded as a positive value and must be reported to the government.

[5] Kinnaman and Fullerton (2000) estimate the price elasticity of recyclables including the correction of the endogenous local policy variables. Their contribution is the correction of the estimation bias that arises from the endogenous policy choices as the explanatory variables in the equation. However, the sample selection bias in this study arises from dependent variables that are omitted due to an endogenous policy choice. Consequently, this paper differs from their work in dealing with the method of correction bias.

[6] For example, refer to Amemiya (1986), ch.10.

and the amount of collection is 0.[7]

$$\epsilon_{1i}, \epsilon_{2i} \sim N(0, \Sigma) \tag{5}$$

where $\Sigma = \begin{pmatrix} 1 & \sigma_{12} \\ \sigma_{21} & \sigma_2^2 \end{pmatrix}$.

Both error terms, ϵ_{1i} and ϵ_{2i}, have a bivariate normal distribution with a mean of 0 and a variance matrix given by Σ. The variance of ϵ_{1i}, however, is normalized to 1. If we regress y_{2i}^* on x_{2i} in Eq. (2), a selection bias will arise as a result of taking the expected value as follows:

$$\begin{aligned} &E(y_{2i}|y_{1i}^*>0) \\ &\quad = \chi_{2i}'\beta_2 + E(\epsilon_{2i}|y_{1i}^*>0) \\ &\quad = \chi_{2i}'\beta_2 + E(\epsilon_{2i}|\varepsilon_{1i} > -\chi_{1i}'\beta_1) \end{aligned} \tag{6}$$

In conclusion, simultaneously estimation by the maximum likelihood method should be used under these conditions.

$$\begin{aligned} L &= j_{y_{1i}=0} P(y_{1i}^* \le 0)\, j_{y_{1i}=1} f(y_{2i}|y_{1i}^*>0) P(y_{1i}^*>0) \\ &= j_{y_{1i}=0} \{1 - \Phi(x_{1i}'\beta_1)\}\, j_{y_{1i}=1} \left(1 - \frac{\sigma_{12}^2}{\sigma_2^2}\right)^{-\frac{1}{2}} \\ &\times \Phi\left\{x_{1i}'\beta_1 + \frac{\sigma_{12}^2}{\sigma_2^2}(y_{2i} - x_{2i}'\beta_2)\right\} \\ &\times \frac{1}{\sigma_2}\phi\left(\frac{y_{2i} - x_{2i}'\beta_2}{\sigma_2}\right) \end{aligned} \tag{7}$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ are probability density function and cumulative distribution function of normal distribution, respectively.

In this paper, the equations given above are estimated and a test for the effect of unit-based pricing on the quantity of each type of recyclable material is undertaken.

The dependent variable of the determination equation for materials recycled by municipalities [Eq. (1)] is a dummy variable. If municipalities decide to collect recyclables, this dummy variable equals 1, and equals 0 otherwise. We assume the recyclable collection of municipalities relative to decide or not depend mainly on saving the scarce landfill space. Since municipalities also have the responsibility of disposing waste appropriately, they desire to minimize landfill waste optimally as well. It is presumable that municipalities located in urban areas strongly desire to reduce burnable and non-burnable waste by means of the collection of recyclables; however, their decision is also constrained by the cost of total solid waste disposal because the collection of recyclables separately with each truck is more expensive than the collection of the entire mixed waste. Under these assumptions, we choose the following independent variables: (1) the log of total waste generation per capita per day of the previous year; (2) the direct landfill rate of the previous year; (3) the ratio of the annual waste disposal cost to the budget expenditure for each municipality in the previous year; and (4) the rate of waste collection by public sectors for the previous year.

Eq. (2) is the recycling equation for households and uses samples selected by the first equation of probit type. The dependent variable is the recycling rate in the equation below.[8]

$$\text{Recycling rate} = \frac{\text{Collection of recyclable materials (ton)}}{\text{Total waste emission (ton)}} \tag{8}$$

This variable takes a logit form and is specified as:

$$\ln\left(\frac{\hat{P}_{ik}}{1 - \hat{P}_{ik}}\right) = \chi_{ik}'\beta_k + \epsilon_{ik}, \tag{9}$$

where $\hat{P}_{ik}$ is the recycling rate for k.

We choose the following independent variables: (1) the average taxable gain per capita; (2) the total waste generation per capita per day (current year); (3) the unit-based price; (4) a dummy variable for two-tier pricing, 1 if two-tier pricing exists and 0 otherwise; (5) a dummy variable for fixed charge pricing, a dummy variable for other pricing methods; (6) the frequency of burnable waste collection per week; (7) the average household size; and (8) the number of youths under 15 years of age. These variables and the recycling equations are commonly used in the literature.

Estimation is attempted by the maximum likelihood method using the SAMPSEL command in TSP. We also estimate using ordinary least squares, and compare the results.

3. Data

This section provides a description of the data. Japanese municipal statistical data on waste generation for the 1997 and 1998 fiscal years are provided by the Japan Waste Management Association (1999, 2000) and the 1997 Personality of Municipalities publication from Asahi Shimbun (2003). The weights of recyclable materials collected by municipalities are reported by the Ministry of Environment (1998). Table 1 provides a description of the sample.

The data on unit-based pricing was assembled through a survey sent to Japanese municipalities. The collection of data was undertaken in several steps. First, data from the Japan Waste Management Association (1999, 2000) was examined to determine which municipalities charge a waste disposal fee, true or false. Then, through a screening of the data it was determined that 611 municipalities charge a disposal fee. Finally, mail and phone surveys were used to investigate the price of a 45 liter bag, or corresponding tag, which was used to carried out unit-based pricing in 1997.[9] Fig. 1 presents the data for price per

[7] For example, although other metals or waste clothes, etc., are recyclables, they are not containers. Some municipalities may collect only other metals or waste clothes. Even if quantities of other metals or waste clothes are provided by curbside collection services and this data is recorded by the municipalities, we consider the municipalities as no recycling municipalities, that is, they are considered to have zero data in terms of amount of collection, $y_{1i}=0$ in the Eq. (4). Therefore, the quantity of recycled materials is zero for this subset of municipalities.

[8] Initially, we assumed that the dependent variable is the per capita weight of recyclable waste generation; however the effects of the multicollinearity caused by the total emissions of independent variable are not satisfactory.

[9] The data was collected over a survey period from July 2001 to January 2002. The price data is for the 2001 fiscal year. It would be more appropriate to use price data for the 1998 fiscal year. However, this data was not available because some municipalities had no record for the unit-price charged. Though there is a distinction in the survey period, it does not change the price in municipalities. Therefore, we assume that municipalities do not change prices in the time period between the survey and this study.

bag or tag. The sample mean is 11.25 Japanese yen, about 9.3 cents, and the mode is 20 Japanese yen, about 16.6 cents. The highest price is 160 Japanese yen, about 132.8 cents.[10] The total sample includes all 3208 Japanese municipalities.

4. Results

The estimation results for the collection of the four types of recyclables are provided in Tables 2 and 3. Table 2 give the ordinary least squares (OLS) with the recycling rate as the dependent variable. In the Table 3, Type 2 Tobit models with the recycling rate are examined. The middle portion of Table 3 provides estimates of the determination equation for municipalities for the Type 2 Tobit model. This is the discrete choice component of the maximum likelihood estimator. The lower portion of the table provides the determination equation for households, which has a continuous dependent variable obtained by discrete sample selection.

4.1. *OLS*

At first glance in the Table 2, the OLS estimates for PET bottles and Paper containers appear to have a bad fit with data. On the other hand in the Table 3, with the exception of Paper containers, ρ is clearly significant for all estimates of the Type 2 Tobit model. This suggests that the effects of sample selection bias, which occurs as a result of selecting samples depending on whether municipalities decide to adopt recycling classifications, cannot be ignored.[11] Consequently, the OLS estimator will be biased if the discrete collection choice of municipalities is not accounted for. A general comparison of the OLS and Type 2 Tobit models shows that a large majority of the coefficients of the OLS have larger absolute values than their counterparts in the Type 2 Tobit model.

4.2. *Type 2 Tobit*

In the middle portion of the Table 3 using the Type 2 Tobit, the log of total emission (previous year) is shown to have a significant effect on the probability of selection. This is an important factor for municipalities when determining which kinds of recyclables they will provide collection services for. In all models, the coefficient for disposal cost has a positive value. Therefore, municipalities with higher disposal costs will probably setup collection services for recyclables in an attempt to avoid disposal costs through recycling. A higher direct landfill rate of the previous year causes a lower selection probability for collection services with the exception of PET bottles and Paper containers. Municipalities with a lower landfill capacity tend to be more willingly adopt recycling programs. This is consistent with the fact that PET bottles and Paper containers are incinerated if they are not reclaimed. The coefficients for the public rate (previous year) are positive for Glass bottles and Cans. We assume that the public rate is set as control variables that explain the status of the municipality.

Table 1 – Sample Description

Variable	Mean	S.D.	Definition
Dummy; glass	0.416	0.493	Dummy variable for waste glasses collection [a]
Dummy; can	0.593	0.491	Dummy variable for beverage cans collection [a]
Dummy; PET bottle	0.170	0.376	Dummy variable for PET bottles collection [a]
Dummy; paper container	0.314	0.464	Dummy variable for paper containers collection [a]
Volume of glasses	22.549	13.441	Volume of glasses collection per capita per gram day [b]
Volume of cans	18.093	13.622	Volume of cans collection per capita per gram day [b]
Volume of PET bottles	1.374	1.145	Volume of PET bottles collection per capita per gram day [b]
Volume of paper containers	0.413	0.460	Volume of paper containers collection per capita per gram day [b]
Recycling rate of glasses	0.049	0.070	Recycling rate of glasses collection [b]
Recycling rate of cans	0.037	0.053	Recycling rate of cans collection [b]
Recycling rate of PET bottles	0.0022	0.0026	Recycling rate of PET bottles collection [b]
Recycling rate of paper containers	0.0007	0.0010	Recycling rate of paper containers collection [b]
Total emission (previous year)	633.6	273.8	Amount of solid waste per capita per gram day [c]
Total emission (current year)	640.6	275.8	Amount of solid waste per capita per gram day [c]
Taxable gain	1.193	0.303	Taxable gain per capita(million yen)
Price	11.30	16.40	Price per bag (yen) [d]
Dummy; Two-tier pricing	0.055	0.229	Dummy variable for two-tier pricing
Dummy; Flat-rate pricing	0.078	0.268	Dummy variable for flat pricing
Dummy; other pricing	0.077	0.266	Dummy variable for other pricing
Frequency; burnable waste	2.109	0.728	Collection frequency of burnable waste per week
Household size	3.183	0.477	Average household size
Under age 15	0.155	0.022	Rate for youth under 15
Landfill rate (previous year)	0.270	0.190	Rate for direct landfill rate
Public rate (previous year)	0.186	0.345	Public sector rate of waste collection
Disposal cost (previous year)	0.016	0.012	Rate for solid waste disposal cost per budget expenditure

[a] If the municipality collects it, 1, or otherwise, 0.
[b] These mean and standard deviation are measured by observed sample.
[c] Exclude balky waste.
[d] Non-unit-based pricing municipalities are set 5 yen per bag.

[10] The average Japanese yen/ U.S. dollar exchange rate in 1997 was 120.4 yen/dollar. When comparing to the average fee per bag in the U.S. and Europe with that in Japan, it must be noted that the volume of a bag in the former countries is 32gal while that in Japan is 12gal. We measured the price per bag on the basis of the 12 gallon bag that is commonly used in Japanese municipalities. Adjusting for the size of bags in the U.S. and Europe, the average fee per bag in Japan is 36 cents and ranges from 16–519cents. In consequence, there is no large difference between the fee per bag between Japan and the U.S. and Europe.

[11] ρ is defined as $\rho=\sigma_{12}/\sigma_2$. This is the correlation coefficient whose denominator σ_1 is 1 from Eq. (7).

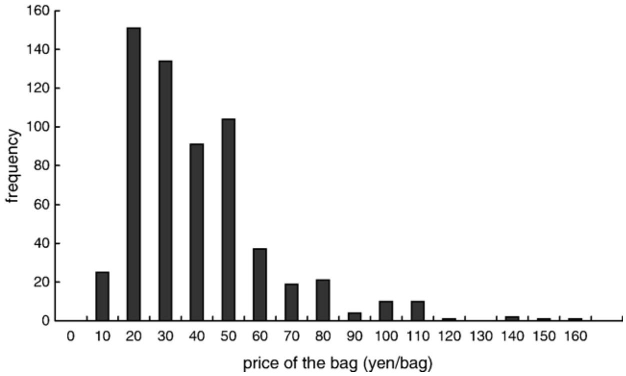

Fig. 1 – Frequency of the price per bag or tag (yen/bag).

The results for the Type 2 Tobit estimates of the determination equation for households are given in the lower portion of table. Price is one of the most interesting policy factors examined. The coefficients are positive, with the exception of paper containers. Why does price matter only for some materials but not for others? Glass bottles, PET bottles, and cans are simple items and easily separable, while it is difficult for households to separate paper containers because they are often compounded with plastic materials, e.g., confectionary packaging. Then, households emit burnable waste, which is far too much of a bother. Overall the results from these analyses suggest that the adoption of a unit-based pricing program is effective for increasing the level of containers and packaging waste that is recycled.

Table 2 – Estimation results for the OLS

Dependent variable	Glass bottles	Cans	PET bottles	Paper containers
Number of obs.	1242	1777	483	690
$\bar{R}^2$	0.162	0.124	0.045	0.053
F value	30.99***	32.47***	3.83***	5.78***
Log of likelihood	−1666.69	−2636.6	−743.606	−1123.18
Constant	−3.957***	−4.227***	−8.397***	−8.865***
	(−13.12)	(−16.1)	(−12.71)	(−16.06)
Taxable gain	−0.112	−0.61***	0.018	−0.051
	(−1.21)	(−7.10)	(0.10)	(−0.33)
Household size	0.704***	0.578***	0.466***	0.647***
	(11.46)	(9.77)	(3.56)	(5.48)
Under age 15	−9.764***	−3.924***	0.807	−5.278**
	(−6.55)	(−3.01)	(0.26)	(−2.07)
Price	0.009***	0.01***	0.016***	0.002
	(4.64)	(5.82)	(2.57)	(0.46)
Dummy; Two-tier pricing	−0.083	0.072	−0.076	0.011
	(−0.84)	(0.69)	(−0.46)	(0.07)
Dummy; Flat-rate pricing	0.381***	0.034	0.302	0.382*
	(3.47)	(0.33)	(1.19)	(1.71)
Dummy; other pricing	0.089	0.167	0.029	0.431**
	(0.81)	(1.65)	(0.13)	(2.00)
Frequency; burnable waste	−0.105***	−0.085**	0.014	−0.116
	(−2.68)	(−2.34)	(0.18)	(−1.57)

Note: Levels of statistical significance: $^{*}p<0.1$, $^{**}p<0.05$, and $^{***}p<0.01$.
Note: *t*-values are given in parentheses.

Taxable gain is a proxy variable for average income per capita household and is considered to represent the opportunity cost of time. The sign is positive for Paper containers equation, and negative for Glass bottles, Cans and PET bottles equations. This result is the same as that of Jenkins et al. (2003). This suggests that paper containers are normal goods and other materials are inferior goods if opportunity cost increases with an increase in household income. Paper packages are frequently used for wrapping luxury goods. In contrast, in the other types of recyclables equations, an increase in household income will decrease the amount of the recycling rate. These results may demonstrate the mixed effects of unobservable consumption and the opportunity cost of time. Normally, consumption grows with income, but if the growing effect of the opportunity cost of time, which is considered to have a negative effect on recycling, dominates the effect of increasing consumption of glass bottles,

Table 3 – Estimation results for the Type 2 Tobit models

Dependent variable	Glass bottles	Cans	PET bottles	Paper containers
Number of obs.	3091	3066	3110	2861
Number of positive obs.	1242	1777	483	690
Log of likelihood	−3591.34	−4523.26	−1988.41	−2558.58
Determination equation by municipalities				
Constant	1.856***	1.923***	−0.615**	−3.209***
	(7.73)	(8.42)	(−2.00)	(−7.92)
Log (Total emission)	−0.369***	−0.293***	−0.118**	0.314***
	(−9.38)	(−7.87)	(−2.35)	(4.75)
Landfill rate	−0.276***	−0.465***	0.004	−0.009
	(−3.03)	(−5.36)	(0.03)	(−0.06)
Public rate	0.107**	0.126**	−0.036	0.118
	(2.22)	(2.54)	(−0.60)	(1.55)
Disposal cost	16.913***	13.153***	21.042***	27.208***
	(8.48)	(6.72)	(9.08)	(10.82)
Recycling equation for households				
Constant	−1.873***	−2.569***	−3.902***	−9.725***
	(−7.01)	(−11.31)	(−6.21)	(−16.79)
Taxable gain	−0.720***	−0.897***	−0.796***	0.281*
	(−8.29)	(−11.74)	(−4.75)	(1.66)
Household size	0.600***	0.467***	0.360***	0.470***
	(10.39)	(8.56)	(2.98)	(3.78)
Under age 15	−8.495***	−4.326***	0.322	−4.184*
	(−6.75)	(−4.10)	(0.13)	(−1.65)
Price	0.007***	0.009***	0.015***	0.001
	(4.46)	(6.13)	(3.08)	(0.21)
Dummy; Two-tier pricing	−0.061	0.014	−0.169	0.034
	(−0.71)	(0.15)	(−1.20)	(0.23)
Dummy; Flat-rate pricing	0.391***	0.189**	0.340	0.315
	(4.06)	(2.17)	(1.61)	(1.42)
Dummy; other pricing	0.131	0.137	0.102	0.389*
	(1.36)	(1.57)	(0.54)	(1.84)
Frequency; burnable waste	−0.076**	−0.083***	−0.091	−0.090
	(−2.50)	(−2.94)	(−1.51)	(−1.23)
σ_2	1.397***	1.464***	1.937***	1.334***
	(32.26)	(44.03)	(17.33)	(22.01)
ρ	−0.939***	−0.940***	−0.946***	0.466***
	(−92.74)	(−114.01)	(−64.1)	(5.12)

Note: Levels of statistical significance: $^{*}p<0.1$, $^{**}p<0.05$, and $^{***}p<0.01$.
Note: *t*-values are given in parentheses.

Table 4 – Estimation results for the Type 2 Tobit models: price elasticities

	Selected sample mean of unit price (yen)	Estimates	
		(Type 2 Tobit: Table 3)	Price elasticity
Glass bottles	10.17	0.007	0.071
Cans	10.50	0.014	0.147
PET bottles	8.15	0.015	0.122
Paper containers	9.45	Not significant	

Note: These estimated price elasticities are evaluated at the selected sample mean of unit price.

cans and PET bottles, the estimated results for glass bottles, cans and PET bottles recycling will be relatively small or perhaps negative. On the other hand, the income effect for the consumption of paper containers is positive. This is consistent with an increase in the consumption of high grade goods.

The variable Household size, the average household size of each municipality, is positive for all types of recyclables. This may also include mixed effects. The first is the effect of decreasing consumption. A large household size will increase household consumption but decrease per capita consumption. Thus decreasing per capita consumption will reduce recycling. The second is the effect of shared housework which occurs for large households. Summing up these two effects, the net effect will be positive.

The variable Under age 15, the rate of youth less than 15 years old, has a negative effect on recycling in Glass bottles, Cans and Paper containers equations. This is probably due to differences in consumption habits within this age group. Its variable doesn't represent the rate of preschoolers, however, they may be difficult to get in the recycling. It will better to get rid of their barrier by introducing policy. We treat the problem with next paper.

The dummy variable for two-tier pricing examines whether or not there is a two-tier price for waste disposal. Two-tier pricing occurs when a municipality supplies a certain number of bags, determined by household size, free of charged. If a household produces a large amount of waste, it will have to pay a disposal fee to buy more bags. This dummy variable is not significant for all equations and models.

The dummy variable for flat-rate pricing, a set annual or monthly fee regardless of the amount of waste emitted, has positive coefficients for Glass bottles and Cans equations. In municipalities that introduce flat-rate pricing, citizens are required to decide whether or not to pay the monthly flat-rate garbage fee. If they decide against paying the monthly garbage fee, they must dispose the household waste themselves; however, they are free to deposit the recyclables they collect at the recycling station. This may lead to a recycling incentive for them. Consequently, the coefficient of flat-rate pricing may have a large positive effect.

A large frequency of burnable waste collection has a negative effect in the Glass bottles and Cans equations. This variable could be considered as a measure of the ease with which households are able to dispose of burnable waste. A higher frequency infers a shorter storage time making it easier for households to produce waste. Therefore, a higher frequency lowers the collection of recyclable materials.

4.3. *Price elasticities*

Table 4 shows our results for price elasticities with respect to each recycling rate. Column 1 contains the selected sample means of unit price (yen) if municipalities collect the relevant types of recyclables. Column 2 contains the coefficients of price in Table 3 estimated by a Type 2 Tobit; however, they are not forms of elasticities. These estimated price elasticities are evaluated at the selected sample mean of unit price.[12]

The estimated arc price elasticity of Kinnaman and Fullerton (2000) is 0.220. However, it is not appropriate to compare the result of Kinnaman and Fullerton (2000) with our results, because our price elasticity represents the increasing amount of the odds-ratio change of the recycling rate that is a logit transformation. Approximately, a 1% increase in unit price leads to a 0.071% increase in the recycling odds-ratio of glass bottles.

5. Conclusions

This study uses unit-pricing data and socio-economic data for all Japanese municipalities. Four types of recyclables data, glass bottles, cans, PET bottles, and paper containers, are used to clarify the impact of unit-based pricing on the level of recycling. A more accurate estimation of the effect of unit-based pricing on the recycling of containers and packaging materials in Japan is proposed, and the factors that determine which items are collected for recycling by municipalities are clarified. Furthermore, the effects of socio-economic factors on the level of recycling for items selected under the Containers and Packaging Law are examined.

Probit types of regressions provide an explanation of the decision-making process undertaking when municipalities select the items to be recycled. Next, regressions explain the factors that affect the level of recycling by households. Their samples are biased by the actions of municipalities, which recyclable items are selected for collection, and are adopted through simultaneously estimation using a Type 2 Tobit model to correct the bias and gain consistent estimator. These results are useful for policy makers and researchers interested in the adoption of recycling programs. Unit-based pricing programs are effective as they encourage the collection of recyclables by households, although the effects differ depending on the type of recyclable material.

Since this recycling Law has been promulgated for over 10 years, the collection of recyclables is growing large. However, municipalities which begin obligated types of recyclable collection has not so increased. We didn't consider the spatial correlation that is like serial correlation of cross section data. We will tackle it in the next paper.

[12] We calculate price elasticities in column 3 as follows: $\partial \ln(y)/\partial x = \beta$, or $\partial \ln(y)/\partial x = (\partial \ln(y)/\partial y)(\partial y/\partial x) = (1/y)(\partial y/\partial x)$, where β is the coefficient of price; x is the variable Price; and $y = P/(1-P)$ from Eq. (9). Further, $\partial \ln\, y/\partial \ln\, x = \epsilon_y = (\partial y/\partial x)(x/y)$, where ϵ_y is price elasticity of y. Therefore, $(\partial \ln(y)/\partial x)x = \epsilon_y = \beta x$.

Acknowledgement

The authors would like to thank three reviewers of this journal for instructive comments on previous version of this paper. This study was subsidized by financial support from Hokusei Gakuen University Special Fund (Individual Academic Research) for 2005. Needless to say, any errors in this paper are ascribed to the author's responsibility.

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