WHY DO MUNICIPALITIES RECYCLE?: USING A BAYESIAN PANEL SPATIAL AUTOREGRESSIVE PROBIT MODEL [*]

Takehiro Usui [†‡] Kazuhiko Kakamu Mitsuko Chikasada

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Abstract

Why do municipalities decide on recyclables collection although it is more expensive than garbage collection? This paper analyzes the determinants of a municipality's decision-making on the collection and separation of recyclables. We investigate the cost minimization behavior of municipalities, such as inter-municipal cooperation in terms of recyclables collection, burning recyclable materials as fuel in incineration facilities, and saving municipal landfill sites owing to its scarcity. We use municipal-level panel data on whether the municipalities in Japan recycle glass bottles, plastic containers, and paper containers. We then apply the Bayesian panel spatial autoregressive probit model. Municipalities having a solid waste burning facility that yields refuse-derived fuel (RDF) are less likely to collect and separate recyclable containers. Instead, they would use the plastic containers for generating energy. Furthermore, the possibility of municipalities effecting recyclables collection is higher for those that possess own landfill sites than for those

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[†] *Corresponding author*: Takehiro Usui, Faculty of Economics, Soka University, 1-236 Tangi-cho Hachioji, Tokyo 192-8577, Japan.

[‡] *Tel.:* +81(42)691-4016; *Fax:* +81(42)691-8232; *E-mail:* usui@soka.ac.jp

that do not. We further find that inter-municipal cooperation involving spatial interaction with neighboring municipalities influences the decision-making and collaborative action of municipalities to implement recyclables collection and reduce costs and that such collaborative action grows stronger year by year.

JEL classification:C11, C23, C25, Q53, R53.

Key words: Municipal solid waste management; Recycling; Panel data; Spatial autoregressive model; Probit model; MCMC.

1 Introduction

Residential waste recycling is widespread today, having increased in many parts of the world during the last quarter-century. Over the past decade, Japan has been promoting the idea of a recycling-based society to prolong the life span of landfill sites and encourage recycling efforts. The Japanese government has encouraged the reducing, reusing, and recycling–the 3Rs–of residential waste under the Basic Law for Establishing a Recycling-based Society. This law has promoted the recycling of plastic containers and packaging materials, resulting in resource conservation, energy-input reduction in incineration facilities, and lengthening of the life span of landfill sites. It is important to consider the budget constraints of municipalities. Recyclables collection increases the total waste disposal costs of municipalities, because recyclables collection has become expensive in spite of the decline in the volume of combustible and incombustible wastes (Porter, 2002). However, some municipalities have introduced recyclables collection. This study examines the reason for this, focusing on the determinants of a municipality's decision on recyclables collection services and identifying the background of the motivation by using certain socio-economic variables that help explain recyclables collection.

Many studies have investigated the recycling motivation of households. For example, Kinnaman and Fullerton (2000), Suwa and Usui (2007), and Allers and Hoeben (2010) examined the demand for waste collection services and recyclables collection. A few studies have dealt with the motivation for starting municipal recyclables collection. Keeler and Renkow (1994) showed that both the need for incineration and the optimal size of an energy recovery facility depend on (1) the underlying costs of the various disposal options and (2) the characteristics of the waste stream. Furthermore, they found that in most cases the allocation of resources for incineration decreases the incentives to recycle. Kinnaman (2005) conducted an empirical study on why municipalities continue to operate recycling programs by using the aggregated state-level panel data from the United States. He found that municipal collection is highly related to certain economic variables. For example, evidence shows that starting recyclables collection in a municipality is related to the proportion of the population living in urban areas, which is a proxy for collection cost. Callan and Thomas (2001) analyzed the cost structure of garbage and recyclables collection by using community-level data from the United States, and found economies of scope in garbage and recyclables collection when introduced simultaneously.

Municipal solid waste services have multiple components, including waste disposal and recycling services. The studies mentioned above except Callan and Thomas (2001) dealt with the efficiency of waste disposal costs as a whole, and did not consider the costs of waste disposal and recycling separately. This could be because it is difficult to separate the total waste disposal costs based on waste for disposal and recycling. Thus far, the Ministry of Economy, Trade and Industry, hereafter, METI, (2007b) has investigated the municipal recycling costs by using a questionnaire survey on the representative municipalities, although the municipal accounts are not differentiated clearly and the definitions of expense items seem to be vague and ad hoc.

In this study, instead of surveying the recycling costs directly, we focus on the municipal behavior, that is, whether the municipality has started recyclables collection. First, the motivation for starting recyclables collection is the lowering of disposal costs through contracting out waste disposal or recyclables collection. Contracting out means that the government employs the private sector to perform some functions, for example, operating school buses or waste collection services (McGuire, 1987). Contracting out waste collection services reduces the recyclables collection costs of municipalities. Therefore, the municipalities that contract out municipal solid waste collection are assumed to have a higher possibility of starting recyclables collection.

Second, in analyzing municipal behavior, it is important to consider inter-municipal collaboration in solid waste management. Bivand and Szymanski (2000) clarified the spatial dependence of adjacent municipalities based on municipal solid waste collection costs. However, they did not clarify the economic structure of cost reduction. Bel *et al*.(2011) analyzed the factors explaining cooperation in solid waste collection among municipalities. Their empirical analysis confirmed that small municipalities should cooperate with other municipalities to reduce their costs of providing waste disposal services. However, Bel *et al*.(2011) did not clarify the economic reasons for spatial dependency relating to recyclables collection services. We now analyze the spatial dependency of recyclables collection services based on scale economies and explain its economic background in this paper. The benefit of scale economies, which is beyond the scope of small municipalities individually, may be one of the main factors driving the cooperation between municipalities.

This study analyzes the determinants of a municipality's decision-making vis-a-vis the collection and separation of recyclables. We shed light on the municipal recyclables collection cost and benefit through the municipal behavior of whether the municipality introduces recyclables collection services. In particular, we focus on the municipal behavior of cost minimization such as inter-municipal cooperation in recyclables collection and contracting out recyclables collection or separation services, burning the recyclable materials, and saving the municipal landfill sites that are scarce. To clarify this deduction, we examine data pertaining to a municipality's behavior, including when it did start to collect different types of recyclable materials such as paper containers, plastic containers, and glass bottles, because each type of material has a different impact on the municipality's behavior in both burning and landfill.

The remainder of this paper is organized as follows. In Section 2, we detail the research background in terms of difference between municipal and national goals vis-a-vis recycling. In Section 3, we introduce the econometric model and data used in this study. In Section 4, we present the estimation results of the Bayesian panel spatial autoregressive probit model. Finally, in Section 5, we present some conclusions and policy suggestions for future research.

2 Research Background

All municipalities are confronted with budget constraints. Therefore, we need to understand the cost structure of recyclables collection in terms of total waste disposal, which is closely related to the introduction of municipal recyclables collection. In this section, we describe the theoretical background of introducing recyclables collection. We explain the background of the Japanese municipal solid waste services programs and highlight the diversity of waste management initiatives–particularly how plastic and paper containers are handled. In this respect, we clarify that municipalities may start recyclables collection from the perspective of cost minimization.

2.1 Institutional Background in Japan

Japan faces a shortage of landfill capacity owing to its relatively small geographical size. The country's direct landfill rate was only 11% in 1995, the lowest among the OECD countries. Compare this figure with the rate of 57% in the United States and 83% in the United Kingdom, for example [1]. Since a country's waste generation and gross domestic product (GDP) are closely related (Daskalopoulos *et al*., 1998), disposable goods, plastic bottles, and paper containers have proliferated in Japan since its rapid economic growth during the 1970s. The Japanese pose too large a challenge for landfill space, because containers and wrappings account for about 60% of their total waste by volume (METI, 2003). Therefore, the Japanese government drafted the Containers and Packaging Recycling Law based on the principle of extended producer responsibility (EPR) (OECD, 2001).

The Japanese Containers and Packaging Recycling Law (hereafter abbreviated as the Recycling Law) went into effect in 1997. The basic principle of the Recycling Law is that every stakeholder has a role to play in recycling. For example, consumers should separate their waste by category, and the municipalities, who are financially responsible for waste collection and disposal costs, should collect the separated waste. Businesses should recycle what has been collected into new products. Concretely speaking, government-designated organizations operate recycling businesses on behalf of specified business entities [2]. By paying recycling fees to the government-designated organizations, these business entities are deemed to have fulfilled their recycling obli-

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[1] See OECD (2008), p.16.

[2] Business entities are defined as follows: (1) manufacturers who use containers and wrappings for shipping their products, (2) retailers and wholesalers who use containers and wrappings for selling merchandise, (3) manufacturers of containers, and (4) importers who import and sell merchandise in containers and wrappings. For further details of the Recycling Law, refer to the METI (2007a).

gations. Thus, the Recycling Law defines the shared responsibilities of each stakeholder–the citizen, producer, recycler, and municipality.

The Japanese government cannot force the municipalities by way of the Recycling Law to provide recyclables collection services. Therefore, the Recycling Law allows the municipalities a diversity of recyclables collection approaches. It is natural to assume that a municipality would freely choose from among many waste-treatment options, especially with respect to plastic and paper containers, given no regulatory power and order of priority for the 3Rs.

In order to consider the municipal choices from these options, we focus on the municipal possession of waste facilities such as incinerators or refuse-derived fuels (RDF), because if the municipalities have incinerators or RDF, they can reduce their waste volume through combustion. The municipalities can choose either recyclables collection or unsorted-waste collection (e.g., mixed waste). If a municipality chooses the recyclables collection of paper or plastic containers, its landfill waste (i.e., that which goes directly or via incineration to a landfill) would be reduced. Therefore, they save the life span of landfill sites and might reduce waste disposal costs. However, the municipality will incur additional collection costs (Central Environment Council, 2005). For example, an incinerator has lower heating value when it reduces the combustible feedstock volume comprising plastic and paper containers [3]. When the municipalities face a shortfall of feedstock, they may use some oil additionally, and this increases their incineration costs. Further, a municipality may tend to build a recyclable waste sorting facility jointly with adjacent municipalities for sharing, giving rise to the possibility of economies of scale by lowering the average cost of solid waste management below the average cost of building a sorting facility on its own within the municipality.

From the above argument, we point out that municipal disposal management is mainly confronted with the following three cost-benefit budget trade-offs: (a) increase in benefit of saving landfill sites by getting rid of some waste and collecting them as recyclable waste vs. increase in the costs of recyclables collection, (b) increase in the cost of additional fuel owing to shortfall of feedstock of paper or plastic containers vs. decrease

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[3] For further technical details, refer to Consonni *et al*.(2005).

in the cost of saving landfill sites by reducing the volume of incineration waste, and (c) cooperation with adjacent municipal entities to build recyclable sorting facility vs. building a facility alone by itself. These three budget trade-offs are all closely related to cost minimization.

2.2 Theoretical Model

We describe our theoretical model for a municipality to introduce recyclables collection. Previous studies have clarified the cost structure of municipal waste collection; for example, see Stevens (1977), Carrol (1995), Callan and Thomas (2001), and Dijkgraaf *et al.*(2003). We focus on the municipal behavior of implementing recyclables collection because we cannot directly observe the cost structure of recyclable waste collection. Here, we assume that the municipalities are rational, and that they initiate collection if the net benefit of recyclables collection is positive. Since the net benefit when a municipality starts recyclables collection will be positive, we can indirectly evaluate the cost structure of the recyclables collection through the municipal behavior. We describe the cost structure as follows:

$$y^* = \begin{cases} B(\cdot) - C(\cdot) \geq 0 \rightarrow y = 1 \\ B(\cdot) - C(\cdot) < 0 \rightarrow y = 0 \end{cases} \tag{1}$$

where y^* is a latent variable; if $y = 1$, the net benefit is positive and the municipality starts collecting recyclables; if $y = 0$, the net benefit is negative and the municipality does not start collecting recyclables.

Using econometric techniques, we clarify why municipalities introduce recyclables collection.

3 Econometric Model and Data

In this section, we introduce the panel spatial autoregressive model proposed by Kakamu *et al.*(2010); it can be used to estimate spatial interactions, as suggested by LeSage and Pace (2009) in the spatial autoregressive model (SAR).

3.1 Panel Spatial Autoregressive Probit Model

Let y_{it} be binary data and $\mathbf{x}_{it}$ be a $1 \times k$ vector of exogenous variables, where i indicates the region ($i = 1, 2, \cdots, n$) and t represents the time period ($t = 1, 2, \cdots, T$). Let w_{ij} denote the spatial weight of the jth region in the ith region, which is given by: (i) $w_{ij} = 0$ for all $i = j$ and (ii) $w_{ij} = 1/m_i$ when the jth region is contiguous with the ith region and $w_{ij} = 0$ otherwise, where m_i denotes the number of regions which is contiguous with the ith region. Note that we have $\sum_{j=1}^{n} w_{ij} = 1$ for all i. In the panel model, we consider that the unobservable component—which is specific to the ith region—affects the dependent variable (e.g., Kakamu and Wago, 2008). α_i is denoted by the unobservable component. Then, the panel spatial autoregressive probit model with parameters ρ_t, α_i, and $\boldsymbol{\beta}$ is written as follows:

$$\begin{aligned} y_{it} &= \begin{cases} 1, & \text{if } z_{it} \geq 0, \\ 0, & \text{if } z_{it} < 0, \end{cases} \\ z_{it} &= \rho_t \sum_{j=1}^{n} w_{ij} z_{jt} + \alpha_i + \mathbf{x}_{it}\boldsymbol{\beta} + \epsilon_{it}, \qquad \epsilon_{it} \sim \mathcal{N}(0, 1), \end{aligned} \tag{2}$$

where z_{it} is a latent variable (see Tanner and Wang, 1987). In (2), ρ_t represents the spatial interaction at time t. Let us define:

$$\begin{aligned} &\boldsymbol{\rho} = (\rho_1, \rho_2, \cdots, \rho_T)', && \boldsymbol{\alpha} = (\alpha_1, \alpha_2, \cdots, \alpha_n)', \\ &\mathbf{z}_t = (z_{1t}, z_{2t}, \cdots, z_{nt})', && \mathbf{z} = (\mathbf{z}_1', \mathbf{z}_2', \cdots, \mathbf{z}_T')', \\ &\mathbf{y}_t = (y_{1t}, y_{2t}, \cdots, y_{nt})', && \mathbf{y} = (\mathbf{y}_1', \mathbf{y}_2', \cdots, \mathbf{y}_T')', \\ &\mathbf{X}_t = (\mathbf{x}_{1t}', \mathbf{x}_{2t}', \cdots, \mathbf{x}_{nt}')', && \mathbf{X} = (\mathbf{X}_1', \mathbf{X}_2', \cdots, \mathbf{X}_T')'. \end{aligned}$$

$\mathbf{W}$ is called the spatial weight matrix (see, e.g., Anselin, 1988), where the element of $\mathbf{W}$ in row i and column j is denoted by w_{ij}, as defined above. Then, the likelihood function of the model (2) is given by:

$$L(\mathbf{y}|\boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mathbf{z}, \mathbf{X}, \mathbf{W}) = \prod_{t=1}^{T} f(\mathbf{y}_t|\rho_t, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mathbf{z}_t, \mathbf{X}_t, \mathbf{W}), \tag{3}$$

where

$$\begin{aligned} f(\mathbf{y}_t|\rho_t, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mathbf{z}_t, \mathbf{X}_t, \mathbf{W}) &= (2\pi)^{-\frac{n}{2}} |\mathbf{I}_n - \rho_t \mathbf{W}| \exp\left(-\frac{\mathbf{e}_t'\mathbf{e}_t}{2}\right) \\ &\quad \times \prod_{i=1}^{n}\prod_{t=1}^{T} \left\{ y_{it}\mathbf{1}_{[0,\infty)}(z_{it}) + (1 - y_{it})\mathbf{1}_{(-\infty,0]}(z_{it}) \right\}. \end{aligned}$$

$\mathbf{I}_n$ indicates the $n \times n$ unit matrix, $\mathbf{e}_t$ is given by $\mathbf{e}_t = \mathbf{z}_t - \rho_t \mathbf{W}\mathbf{z}_t - \mathbf{X}_t\boldsymbol{\beta} - \boldsymbol{\alpha}$, and $\mathbf{1}_{(a,b)}(x)$ denotes the indicator function, which takes 1 when x lies on the interval between a and b.

3.2 Definition of Variables

In this subsection, we define the dependent and independent variables with the use of a panel spatial autoregressive probit model. The descriptive statistics based on the dependent and independent variables are shown in Table 1.

3.2.1 Dependent variables

We use three sets of binary data as dependent variables in our estimations. The data pertain to whether a municipality introduces recyclables collection of waste materials such as glass bottles, plastic containers and wrappings, and paper containers and wrappings as defined by the Recycling Law. The dummy variable for the binary data takes a value of 1 if the municipality collects a certain type of presorted recyclables or commingled recyclables and then sorts them by type; otherwise, the dummy variable takes a value of zero. As previously mentioned in section 2.1, the decisions on whether to collect and store recyclable containers and packaging as well as the types of recyclables to be collected are left to the discretion of the municipalities. It seems that the factors motivating a municipality's decision to implement recyclables collection also vary according to the types of recyclables at issue. For example, there are a variety of waste-treatment solutions for plastic or paper containers and wrappings among the municipalities, because these types of materials, as previously mentioned in section 2, are combustible or can be used for incineration, waste-to-energy (WtE) technology, RDF, or recycling. Owing to scarcity of municipal landfills, incinerators or RDF are used to reduce the volume of waste through combustion. Meanwhile, recent incinerators also have WtE functionality, that is, they recover energy [4]. In other words, these combustible materials can be handled in two ways, that is, recycling and incineration. Therefore, the possession of incineration facilities can adversely affect a municipality's decision

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[4] For example, the WtE process produces by-products (i.e., electricity or hot vapor), and the RDF can use the waste directly as fuel. WtE technology has been used not only in Japan but also in many European countries (Bogner *et al*., 2008).

to implement recyclables collection. On the other hand, glass bottles are not combustible, and so the possession of incineration facilities would not prevent the municipalities from implementing recyclables collection of such waste. Therefore, we have created dependent variables for each type of material.

Table 2 gives the proportion of municipalities that collect or separate each type of waste. The proportion and number of municipalities seem to have grown year by year across all types of recyclables. The collection of glass bottles already seems to be widely distributed, because this is a traditional recyclables collection. Meanwhile, the collection of paper and plastic containers seems to have been rarely introduced, since attempts at recycling such waste items are rather rare for municipalities. Figures 1–9 outline the spatial distribution of the introduction of each type of recyclables collection from 2000 to 2002.

3.2.2 Independent variables

Now, we explain the independent variables used in our models; these can be divided into three categories: incineration and RDF, landfill, and others.

We interpret the coefficients in terms of costs and benefits: if a municipality starts recyclables collection, its benefits would increase through a reduction in collection costs of combustible and incombustible waste (or mixed waste). It would also save the opportunity cost of landfill siting. In contrast, some costs increase: for example, those related to automobiles used for recyclables collection, labor, and the creation of separating facilities for handling recyclable waste (Porter, 2002). To omit simultaneous decisions vis-a-vis recyclables collection and the facilities' choices, we consider a one-year lag in terms of facility variables.

Incineration and RDF We pick up the independent variables relating to WtE facilities, such as incineration and RDF facilities. We define a dummy variable for possessing at least one incineration facility inside the municipality, regardless of whether it is solely owned or shared with other municipalities. The expected sign of the estimated coefficient for plastic and paper containers is negative, while that of glass bottles is positive; this is because a municipality may have a negative attitude toward initiating recyclables collection of paper or plastic containers in increasing the energy efficiency of an incineration facility. Otherwise, a municipality may need to add heating oil to burn wet waste.

For a cost-benefit interpretation, a municipality will save the cost of additional oil by deciding not to start paper or plastic container collection, holding all other relevant factors constant. From the perspective of life-cycle assessment, the decision not to recycle might increase the net CO_2 emissions more than in the case of paper and plastic container collection and result in the direct reduction of additional oil and indirect increase in the additional energy and raw material inputs of crude oil (Waste Management and Recycling Department, 2009).

We also define a dummy variable for waste power generation. This variable is defined in terms of whether a municipality has an incineration plant supplemented with an electric generator. The expected sign of the coefficient is negative for paper and plastic containers since these materials have such a high caloric content that the facility can produce a substantial amount of electricity for sale. Therefore, a municipality will not start recyclables collection for such recyclable waste from a cost-benefit perspective. However, the coefficient would take a positive sign for glass bottles in cases of reducing incombustible waste.

The equation includes a dummy variable for the possession of RDF facilities; this coefficient is expected to be negative because RDF facilities process combustible recyclables such as paper and plastic containers. Municipalities that have RDF facilities are aware of their benefits and are therefore highly unlikely to start recyclables collection programs. The scenario here is similar to that with the sign of the coefficients of the dummy variable for waste power generation.

Landfill Here, we address landfill scarcity qualitatively. We define two landfill dummy variables, one representing the possession of landfill sites inside a single municipality, and the other representing the sharing of landfill sites with adjacent municipalities [5].

The incentive to conserve landfill differs with the type of landfill possession, because owning a landfill site solely is like owning a private good, whereas sharing a site with adjacent municipalities is like sharing a public good that cannot be used exclusively. Therefore, the expected sign of the coefficient of landfill sites within a

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[5] In the estimation, to avoid multicollinearity, we drop the dummy variables when no landfill site is owned.

municipality is positive in case there is no other possession and negative in case the landfill site is shared.

To interpret the introduction of recyclables collection programs from an economic perspective, one could assert that if the net present value of the benefits of such a program has a positive sign, a municipality will initiate it. The following assumptions are inherent in this assertion: the benefits (calculated at the present value) of recyclables collection mitigate the opportunity costs associated with landfill by removing recyclable waste from the combustible or incombustible waste; combustible or incombustible waste collection costs come down (we exclude labor costs because we use its proxy variable); and costs (calculated at the present value) include the additional collection costs associated with recyclables collection programs.

We add a variable for landfill capacity (year), that is, the number of years a municipality can bury waste at the current rate of landfill waste production in order to consider quantitatively the nature of land scarcity. The expected sign for all equations is negative.

Other variables Finally, we define the other control variables that affect the benefits and costs of recyclables collection.

We introduce the per capita wage rate of municipal employees per year. The variable proxies the degree of collection cost, which mainly relates to the labor costs for collection. We expect the sign to be negative, because the higher the labor cost, the lower is the probability of a recyclables collection program being initiated. More specifically, the marginal collection costs of recyclables are more expensive than the marginal collection costs of mixed waste [6]. The amount of total labor cost in a municipality is divided by the number of municipal employees.

The proportion of contracting out is defined by the proportion of waste collection consigned to a private collector (in tons). In many municipalities, collection is consigned to private companies in order to reduce waste management costs. Therefore, the higher the private consignment ratio, the lower is the probability of recyclables collection or separation.

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[6] The METI (2005) provides evidence of this via a cost-benefit analysis based on the Recycling Law, undertaken via a bottom-up survey of some municipalities.

Additionally, we define the amount of total waste generated per year as a variable, which is implied as a proxy of scale. If the amount of waste increases, the probability of a municipality introducing recyclables collection or separation programs is assumed to increase because of the merits of scale; in particular, the average cost of waste separation will be reduced in waste separation facilities.

Population density (person per km^2) is a proxy of land price for waste separation facilities [7]. If the population density is high, the expected sign of this coefficient will be negative, because the property cost of waste separation facilities will be higher.

We add a dummy–Year t (benchmark year = 2000)–which will absorb the macro-level shock of all municipalities.

3.3 Data

In this section, we discuss the nature of the data used in this study.

The dependent variables are based on data issued by the Ministry of the Environment (2001–2003); the data are issued every year after a survey of all the municipalities in Japan. We use the recyclables collection data pertaining to whether the municipalities have initiated a recyclables collection program. We assume that municipalities carry out recyclables collection or separation via hand or machine sorting.

The independent variables pertaining to the facilities, that is, incineration, RDF, and landfill variables, and the data pertaining to volumes of waste are obtained from a national census of waste management of all municipalities conducted by the Ministry of the Environment (1999–2002).

The demographic variables of population density and labor price are obtained from the Basic Resident Register (nationwide census) and an appraisal of the municipalities' accounts, respectively.

We captured the data of totally 3,252 municipalities for 2000. We used panel data from 2000 to 2002 because this period coincides with the introduction of the Recycling Law. We avoided using data pertaining to after 2002 because the merging of municipalities in 2003 might have had a considerable effect on the municipalities' decisions vis-a-vis implementation of collection programs and the choice of materials to be collected.

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[7] We use this proxy because we are unable to acquire any land price variable data

After excluding outliers and missing values, we used the data of 2,951 municipalities for our final estimation.

We used a contiguity-based spatial weight matrix for this study, defining two areas as adjacent if they share a border or vertex. We estimate equations for each type of recyclable material, using balanced panel data of 2,951 municipalities for $\times$ 3 years, as already mentioned, and we apply the spatial autoregressive panel probit model.

4 Results

In this section, we show the estimation results obtained by using the spatial autoregressive panel probit model. We ran the Markov chain Monte Carlo (MCMC) algorithm, applying 50,000 iterations and discarding the first 10,000 iterations.

For the prior distributions, we set the hyper-parameters as follows:

$$\boldsymbol{\beta}_0 = 0, \;\; \boldsymbol{\Sigma}_0 = 100 \times \mathbf{I}_k, \;\; \mu_0 = 0, \;\; \xi_0^2 = 100, \;\; \nu_0 = 2, \;\; \lambda_0 = 0.01. \tag{4}$$

The estimation results are shown in Table 3, 4, and 5.

4.1 Independent Variables

Incineration and RDF The estimated coefficients of all the variables related to incineration facilities, such as the dummy variables for possessing incineration facilities and for waste power generation, included zero in the 95% credible intervals [8]. On the other hand, the estimated coefficient of the dummy variable for RDF facilities did not include zero in the 95% credible intervals in the equation for plastic containers, and, as expected, the sign is negative (see Table 5). Plastic containers can particularly be used as solid waste fuel, and some municipalities may consider them important for use in RDF facilities and decide not to recycle plastics in order to reduce their RDF facility costs.

The cost of saving landfill sites was controlled for in the equation, and so it does not have to be considered here. If a municipality with an RDF facility recycles plastics, it would increase not only their explicit costs

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[8] These results are estimated by the Bayesian method. Therefore, we interpret our coefficients in the Bayesian style.

(such as the collection and separation costs for recycling) but also their implicit costs (such as the benefits from supplying fuels that are forsaken to pursue recyclables collection).

Landfill We found evidence that the degree of landfill site ownership of a municipality affects the probability of initiating collection and separation services. The estimated coefficient of a dummy variable for being the sole owner of a landfill site was positive and did not include zero in the 95% credible intervals for all equations, including glass bottles and plastic and paper containers (Table 3, 4, and 5). In other words, the municipalities that have own landfill sites show a higher probability of offering collection or separation services for recycling than those that do not.

This shows that the net benefit of a municipality possessing landfill sites is greater than zero (positive). Concretely, the following cost structure can be inferred: The collection and separation of recyclables enable the municipalities to reduce the volume of combustible and incombustible waste, ultimately leading to a reduction in landfill waste and saving the life span of landfill sites. Through collection and separation, the municipalities can save on the opportunity costs of land use (increase in benefits), and on the cost of collecting and transporting combustible and incombustible waste (increase in benefits) [9].

Other variables The estimated coefficients of the wage-rate variable do not include zero in the 95% credible interval and are found negative for the glass bottle and plastic container equations. These results imply that the higher the labor cost for collection and separation, the more reluctant are the municipalities to implement recyclables collection and separation programs.

This implies that the net benefit from recyclables collection is negative. According to empirical evidence from Stevens (1994) and Porter (2002), an increase in the costs of collecting recyclables is much greater in absolute value than a decrease in the cost of collecting combustible and incombustible wastes. In other words, recyclables collection becomes expensive in spite of a decline in volume of combustible and incombustible waste. Hence, the higher the wage rate, the greater is the cost of introducing recycling. These could be the

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[9] Labor cost is assumed to be controlled for by the wage-rate variable.

reasons why the municipalities with higher wage rates are reluctant to implement recycling programs.

The estimated coefficients on the total waste generation variables have positive signs and do not include zero in the 95% credible intervals for glass bottles or paper containers; this is consistent with our expectation. The implication here is that the higher the total waste generation in the previous year, the higher is the probability of a municipality introducing recyclables collection or separation programs. This result provides evidence of scale economies in the establishment of recycling facilities.

The coefficient on the percentage of contracting out is positive and does not include zero in the 95% credible interval for paper and plastic containers. This result indicates that the higher the municipal consignment ratio, the higher is the probability of municipalities implementing collection or separation programs. This could be because the consigned private company-run recyclables collection programs incur lower costs than the programs directly run by municipalities [10]. Thus, such municipalities are likely to introduce paper and plastic container collection. Our results are similar to those of Stevens (1994), Dijkgraaf *et al*.(2003), and Usui (2009) who studied the contracting out of refuse collection. They show evidence for political patronage and the wealth of local governments being grounds for contracting out, besides the possible efficiency gains from contracting. We thus obtained new evidence on recyclables collection relating to contracting out.

If contracting out is applied to recycling, the consigned private company-run recyclables collection would be less expensive. What a municipality compares here is (a) landfill costs in the case of a municipality not implementing recycling (if the municipality does not possess a landfill site, ”landfill costs” means the costs to pay to another municipality with landfill sites), and (b) the recyclables collection costs. If the net benefit from implementing recycling [(a) minus (b)] were positive, it would implement recyclables collection. Now, by contracting out, the municipality can reduce recyclables collection costs (b), indicating the increasing possibility of (a) minus (b) being positive. Therefore, the higher the percentage of waste collection outsourced to private companies, the more likely it is for recyclables collection to be implemented.

The coefficients of population density have negative signs and do not include zero in the 95% credible

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[10] Most consigned private companies already have their own separation facilities and so can provide collection services at lower costs.

interval in the glass bottle equation. This variable was used as a proxy for cost of building a recycling facility. Data on the cost of land for recyclable materials separation facilities are not available in Japan. The property costs of waste separation facilities become higher when the land prices increase, preventing municipalities from implementing recyclables collection services.

4.2 Spatial Interaction

The spatial interaction at time t, ρ_t, was positive and did not include zero in the 95% credible intervals for all years and equations. A municipality's implementation of recyclables collection or separation might have a spatial interaction with its neighboring municipalities. A municipality may construct a recyclable waste sorting facility jointly with its adjacent municipality if both of them can gain from the benefit of cost-effectiveness of merger with regard to building a recyclable facility. The coefficients of glass bottles are the largest among the equations. Glass bottle collection programs have been traditionally implemented by many municipalities prior to the Recycling Law (once again, see Table 2). Therefore, the estimated results can be interpreted thus: recycling facilities are often shared among adjacent municipalities in order to reduce separation costs, making use of scale economies [11].

4.3 Random Effect

Figures 10, 11, and 12 are graphic representations of spatial patterns of the estimated random effects and posterior means of α_i for each equation. The darker the shade of blue for a municipality in this figure, the lower is the possibility that it will introduce recyclables collection; conversely, the darker the shade of pink, the greater is the possibility of recyclables collection. Each map seems to capture an unobserved effect among the adjacent municipalities, which could be distinct from spatial interaction terms ρ_t (Kakamu and Wago, 2008).

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[11] We additionally estimate the other weight matrices, such as adjacent income and population matrices. The results are quite similar to those presented here, indicating the robustness of our model in terms of selection of variables. Those results are available from the authors upon request.

5 Conclusion

The purpose of this study was to estimate a municipality's decision factors relating to the collection and separation of recyclable containers and packaging material under the Japanese Recycling Law. We used a spatial autoregressive panel probit model from a Bayesian perspective.

This study focused on the various waste management objectives of the local governments and the differences between the approaches of local and national governments. In particular, we investigated the municipalities' cost minimization behavior, such as inter-municipal cooperation in recyclables collection, incineration of recyclable materials, and saving scarce municipal landfill sites. We used municipal recyclables collection data, which relate directly to the issue of waste management, to show why some municipalities have recycling programs while others do not.

The municipal decision to collect recyclable material for incineration enables cannibalizing recyclable collections: municipalities with a refuse-derived fuel facility are less likely to collect and separate recyclable containers because they can use plastic containers to generate energy. The decision of a municipality to implement recyclables collection depends on whether it owns landfill sites, and not on landfill capacity. In particular, the probability of a municipality introducing recyclables collection is higher when it owns landfill sites than when it shares a site with another municipality or has no possession whatsoever. Spatial interaction constitutes a topic of concern drawing increased attention in economics research. Our econometric model allows us to control for a municipality's spatial interaction with adjacent municipalities and provides us an accurate estimation with the use of available panel data. The coefficients of spatial correlation do not include zero in the 95% credible intervals and are positive for all years and all equations. This means that a municipality's implementation of recyclables collection or separation programs shows spatial interaction with its neighboring municipalities. This is owing to collaborative efforts to implement a recyclables facility and reduce costs; these collaborative efforts are seen to grow stronger year by year.

With regard to policy recommendations, the national government may find it necessary to offer some sort of financial incentives to municipalities if they want them to introduce recyclables collection programs. The estimated coefficients on the variable of total waste generation showed positive signs. This result provides evidence of scale economies with regard to the establishment of recycling facilities. This result further shows that small municipalities that do not benefit from scale economies when building sorting facilities may need financial support to implement recyclables collection services.

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A Joint Posterior Distribution

Since we utilize a Bayesian method for estimation, we adopt the following hierarchical prior:

$$\pi(\boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mu, \xi^2) = \left\{ \prod_{t=1}^{T} \pi(\rho_t) \right\} \left\{ \prod_{i=1}^{n} \pi(\alpha_i | \mu, \xi^2) \right\} \pi(\boldsymbol{\beta}) \pi(\mu) \pi(\xi^2),$$

which is used in Kakamu and Wago (2008); there, μ and ξ^2 indicate the mean and variance of α_i, respectively.

Given the prior density $\pi(\boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mu, \xi^2)$ and the likelihood function (3), the joint posterior distribution can be expressed as:

$$\begin{aligned}
&\pi(\boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mu, \xi^2 | \mathbf{z}, \mathbf{y}, \mathbf{X}, \mathbf{W}) \\
&\qquad \propto \pi(\boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mu, \xi^2) \prod_{t=1}^{T} f(\mathbf{y}_t | \rho_t, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mathbf{z}_t, \mathbf{X}_t, \mathbf{W}). \qquad (5)
\end{aligned}$$

We assume the prior distributions, i.e., $\pi(\rho_t)$, $\pi(\alpha_i|\mu, \xi^2)$, $\pi(\boldsymbol{\beta})$, $\pi(\mu)$ and $\pi(\xi^2)$, as follows:

$$\begin{aligned}
&\rho_t \sim \mathcal{U}(-1, 1), \qquad \alpha_i|\mu, \xi^2 \sim \mathcal{N}(\mu, \xi^2), \qquad \boldsymbol{\beta} \sim \mathcal{N}(\boldsymbol{\beta}_0, \boldsymbol{\Sigma}_0), \\
&\mu \sim \mathcal{N}(\mu_0, \xi_0^2), \qquad \xi^2 \sim \mathcal{IG}(\frac{\nu_0}{2}, \frac{\lambda_0}{2}),
\end{aligned}$$

where $\mathcal{IG}(a, b)$ denotes the inverse gamma distribution with the scale parameter a and the shape parameter b.

A.1 Posterior Simulation

From the joint posterior distribution (5), we can implement the MCMC method. The Markov chain sampling scheme can be constructed from the full conditional distributions of $\{\mathbf{z}_t\}_{t=1}^T$, $\{\rho_t\}_{t=1}^T$, $\{\alpha_i\}_{i=1}^n$, $\boldsymbol{\beta}$, μ, and ξ^2, which are shown as follows. Using the Gibbs sampler (e.g., see Gelfand and Smith, 1990), the random draws from the posterior distribution of $\{\mathbf{z}_t\}_{t=1}^T$, $\{\rho_t\}_{t=1}^T$, $\{\alpha_i\}_{i=1}^n$, $\boldsymbol{\beta}$, μ, and ξ^2 are generated.

A.1.1 Sampling $\{\mathbf{z}_t\}_{t=1}^T$

In the case of the probit model, it is required to generate the latent variables $\{\mathbf{z}_t\}_{t=1}^T$. Let us define $\mathbf{z}_{-it} = \{z_{1t}, \cdots, z_{i-1,t}, z_{i+1,t}, \cdots, z_{nt}\}$, where z_{it} is excluded from $\mathbf{z}_t$. Tanner and Wong (1987) propose a data augmentation method to generate latent variables, and we make use of that here. The full conditional distribution of z_{it} follows:

$$z_{it}|\rho_t, \alpha_i, \boldsymbol{\beta}, z_{-it}, \mathbf{y}_t, \mathbf{x}_{it}, \mathbf{W} \sim \mathcal{N}_{a_{it} \le z_{it} \le b_{it}}(\hat{z}_{it}, 1), \qquad (6)$$

with $\hat{z}_{it} = \alpha_i + \sum_{j=1}^n \rho_t w_{ij} y_{jt} + \mathbf{x}_{it}\boldsymbol{\beta}$. $\mathcal{N}_{a<z<b}(\mu, \sigma^2)$ denotes the truncated normal distribution with mean μ and variance σ^2, where z is distributed between a and b. In this study, truncation is set to $(a_{it}, b_{it}) = (0, \infty)$

when $y_{it}=1$, and $(a_{it},b_{it})=(-\infty,0)$ when $y_{it}=0$.

A.1.2 Sampling $\{\rho_t\}_{t=1}^T$

Define $\boldsymbol{\rho}_{-t}=\{\rho_1,\cdots,\rho_{t-1},\rho_{t+1},\cdots,\rho_T\}$, where ρ_t is excluded from $\boldsymbol{\rho}$. From (5), the full conditional distribution of ρ_t is written as:

$$p(\rho_t|\boldsymbol{\rho}_{-t},\boldsymbol{\alpha},\boldsymbol{\beta},\mu,\xi^2,\mathbf{z},\mathbf{y},\mathbf{X},\mathbf{W})\propto|\mathbf{I}_n-\rho_t\mathbf{W}|\exp\left(-\frac{\mathbf{e}_t'\mathbf{e}_t}{2}\right), \tag{7}$$

with $\mathbf{e}_t=(\mathbf{I}_n-\rho_t\mathbf{W})\mathbf{z}_t-\mathbf{X}_t\boldsymbol{\beta}-\boldsymbol{\alpha}$. Using the Metropolis algorithm (e.g., see Tierney, 1994), a random draw of ρ_t is sampled from the conditional distribution $p(\rho_t|\boldsymbol{\rho}_{-t},\boldsymbol{\alpha},\boldsymbol{\beta},\mu,\xi^2,\mathbf{z},\mathbf{y},\mathbf{X},\mathbf{W})$.

The following Metropolis step is used: (i) sample ρ_t^{new} from:

$$\rho_t^{new}=\rho_t^{old}+c_t\eta_t,\qquad \eta_t\sim\mathcal{N}(0,1), \tag{8}$$

where c_t is called the tuning parameter and ρ_t^{old} denotes the random draw previously sampled, (ii) evaluate the acceptance probability:

$$\omega(\rho_t^{old},\rho_t^{new})=\min\left(\frac{p(\rho_t^{new}|\boldsymbol{\rho}_{-t},\boldsymbol{\alpha},\boldsymbol{\beta},\mu,\xi^2,\mathbf{z},\mathbf{y},\mathbf{X},\mathbf{W})}{p(\rho_t^{old}|\boldsymbol{\rho}_{-t},\boldsymbol{\alpha},\boldsymbol{\beta},\mu,\xi^2,\mathbf{z},\mathbf{y},\mathbf{X},\mathbf{W})},1\right),$$

and (iii) set $\rho_t=\rho_t^{new}$ with probability $\omega(\rho_t^{old},\rho_t^{new})$ and $\rho_t=\rho_t^{old}$ otherwise. The proposed random draw of ρ_t generated from (8) takes the real value within the interval $(-\infty,\infty)$, although the prior distribution of ρ_t lies in the interval between -1 and 1. If the candidate of ρ_t does not lie in the interval $(-1,1)$, the conditional posterior should be zero; accordingly, the proposed value would be rejected with a probability of one (see Chib and Greenberg, 1998). We need the tuning parameter c_t in sampling ρ_t. In the numerical example discussed below, we choose the tuning parameter, such that the acceptance rate is between 0.4 and 0.6 (see Holloway *et al.*, 2002).

A.1.3 Sampling the other parameters

The full conditional distribution of $\boldsymbol{\beta}$ is:

$$\boldsymbol{\beta}|\boldsymbol{\rho},\boldsymbol{\alpha},\mu,\xi^2,\mathbf{z},\mathbf{y},\mathbf{X},\mathbf{W}\sim\mathcal{N}(\hat{\boldsymbol{\beta}},\hat{\boldsymbol{\Sigma}}), \tag{9}$$

with $\hat{\boldsymbol{\beta}} = \hat{\boldsymbol{\Sigma}}\{\mathbf{X}'(\mathbf{z} - (\boldsymbol{\Psi} \otimes \mathbf{W})\mathbf{z} - \boldsymbol{\Delta}\boldsymbol{\alpha}) + \boldsymbol{\Sigma}_0^{-1}\boldsymbol{\beta}_0\}$, $\boldsymbol{\Delta} = (\mathbf{1}_T \otimes \mathbf{I}_n)$, $\mathbf{1}_T$ is a $T \times 1$ unit vector, and $\hat{\boldsymbol{\Sigma}} = (\mathbf{X}'\mathbf{X} + \boldsymbol{\Sigma}_0^{-1})^{-1}$. The element of $\boldsymbol{\Psi}$ in row t and column s is given by ρ_t for $t = s$ and zero for $t \neq s$, i.e., $\boldsymbol{\Psi} = diag(\boldsymbol{\rho})$.

$\mathbf{z}$, $\boldsymbol{\rho}$, and $\boldsymbol{\beta}$, (2) are written as:

$$z_{it} - \sum_{j=1}^{n} \rho_t w_{ij} z_{jt} - \mathbf{x}_{it}\boldsymbol{\beta} = \epsilon_{it}, \qquad \epsilon_{it} \sim \mathcal{N}(\alpha_i, 1).$$

Let us define $\boldsymbol{\alpha}_{-i} = \{\alpha_1, \cdots, \alpha_{i-1}, \alpha_{i+1}, \cdots, \alpha_n\}$, where α_i is excluded from $\boldsymbol{\alpha}$. The full conditional distribution of α_i is as follows:

$$\alpha_i | \boldsymbol{\rho}, \boldsymbol{\alpha}_{-i}, \boldsymbol{\beta}, \mu, \xi^2, \mathbf{z}, \mathbf{y}, \mathbf{X}, \mathbf{W} \sim \mathcal{N}(\hat{\alpha}_i, \hat{\xi}^2), \tag{10}$$

with $\hat{\alpha}_i = \hat{\xi}^2\{\sum_{t=1}^{T}(z_{it} - \sum_{j=1}^{n} \rho_t w_{ij} z_{jt} - \mathbf{x}_{it}\boldsymbol{\beta}) + \xi^{-2}\mu\}$ and $\hat{\xi}^2 = (T + \xi^{-2})^{-1}$.

The full conditional distributions of μ and ξ^2 are given by:

$$\begin{aligned} \mu | \boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \xi^2, \mathbf{z}, \mathbf{y}, \mathbf{X}, \mathbf{W} &\sim \mathcal{N}(\hat{\mu}, \hat{\sigma}^2), & (11) \\ \xi^2 | \boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mu, \mathbf{z}, \mathbf{y}, \mathbf{X}, \mathbf{W} &\sim \mathcal{IG}(\frac{\hat{\nu}}{2}, \frac{\hat{\lambda}}{2}), & (12) \end{aligned}$$

with $\hat{\mu} = \hat{\sigma}^2(\xi^{-2}\sum_{i=1}^{n}\alpha_i + \xi_0^{-2}\mu_0)$, $\hat{\sigma}^2 = (\xi^{-2}n + \xi_0^{-2})^{-1}$, $\hat{\nu} = n + \nu_0$ and $\hat{\lambda} = (\boldsymbol{\alpha} - \mu)'(\boldsymbol{\alpha} - \mu) + \lambda_0$.

Thus, from (6), (7), and (9)–(12), the random draws of $(\mathbf{z}, \boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \mu, \xi^2)$ are easily sampled from the Gibbs sampler (e.g., Gelfand and Smith, 1990).

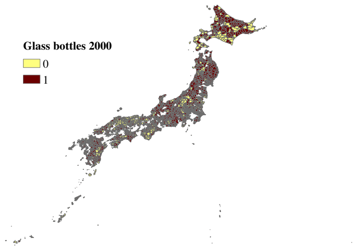

Figure 1: Spatial distribution related to introduction of glass bottle collections, 2000

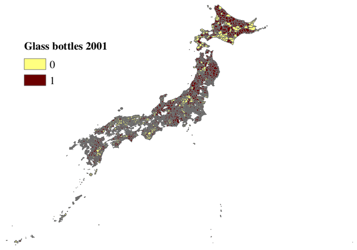

Figure 2: Spatial distribution related to introduction of glass bottle collections, 2001

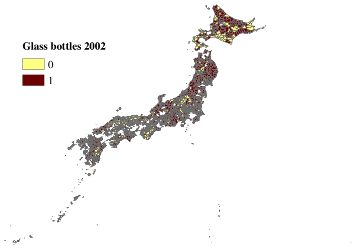

Figure 3: Spatial distribution related to introduction of glass bottle collections, 2002

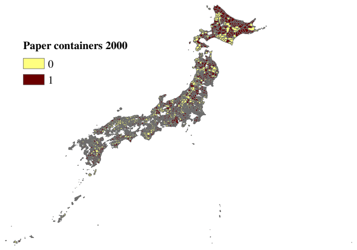

Figure 4: Spatial distribution related to introduction of paper container collections, 2000

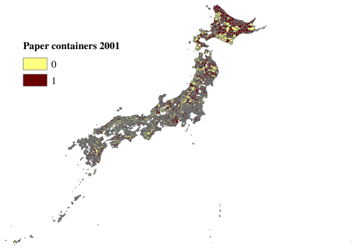

Figure 5: Spatial distribution related to introduction of paper container collections, 2001

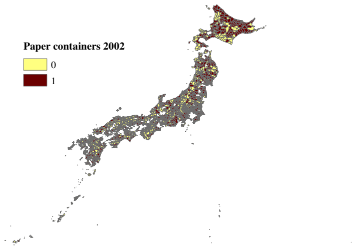

Figure 6: Spatial distribution related to introduction of paper container collections, 2002

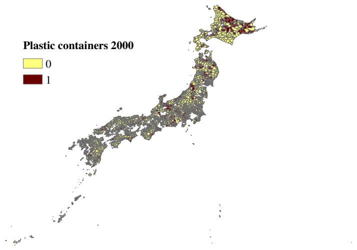

Figure 7: Spatial distribution related to introduction of plastic container collections, 2000

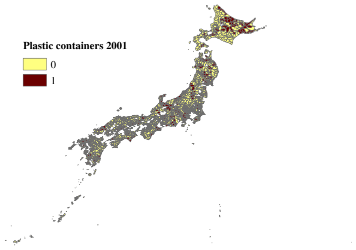

Figure 8: Spatial distribution related to introduction of plastic container collections, 2001

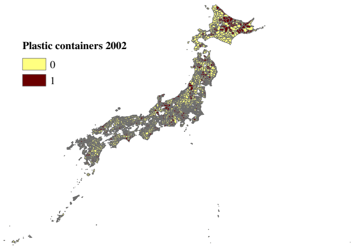

Figure 9: Spatial distribution related to introduction of plastic container collections, 2002

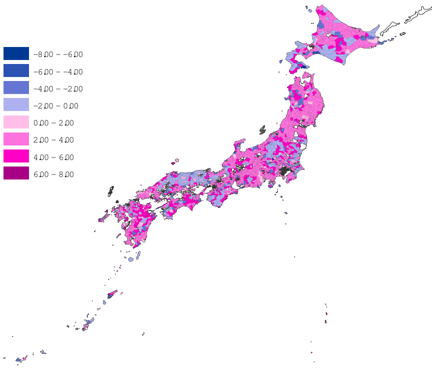

Figure 10: Spatial distribution of posteria mean of the random effects in glass bottle, α_i

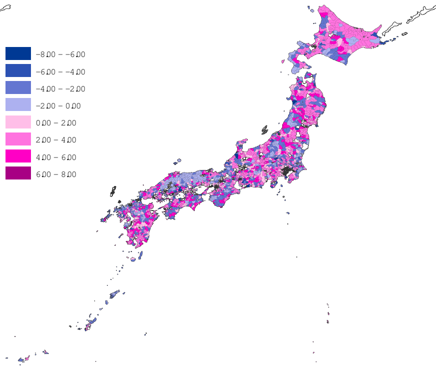

Figure 11: Spatial distribution of posteria mean of the random effects in paper container, α_i

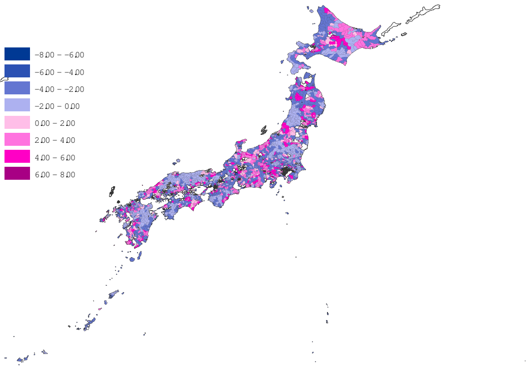

Figure 12: Spatial distribution of posteria mean of the random effects in plastic container, α_i

Table 1: Descriptive statistics

Variables	Mean	s.d.	Min	Max
Glass collection dummy $^{(a)}$	0.676	0.468	0	1
Plastic collection dummy $^{(a)}$	0.268	0.443	0	1
Paper collection dummy $^{(a)}$	0.521	0.500	0	1
Dummy: possessing incineration $^{(b)}$	0.916	0.277	0	1
Dummy: possessing waste power generation $^{(b)}$	0.089	0.285	0	1
Dummy: possessing RDF $^{(b)}$	0.018	0.131	0	1
Dummy: possessing landfill solely $^{(b)}$	0.290	0.454	0	1
Dummy: sharing landfill $^{(b)}$	0.505	0.500	0	1
Landfill capacity (year) $^{(b)}$	28.530	256.762	0	8345
Waste generation (tons) $^{(b)}$	8650	19692	29	292735
Wage rate (per capita · year: 1000 yen) $^{(b)}$	9039	828	5366	12632
Population density (per km^2) $^{(b)}$	470	808	1	6196
Proportion of municipal collection (%) $^{(b)}$	0.258	0.398	0	1

Note: 1 Euro = 100 yen (Jan 2012).

Note: (a) data period from 2000 to 2002, and (b) from 1999 to 2001.

Table 2: Sample mean of recyclable collection rate, sorted by year: glass bottle, paper containers, and plastic containers

Year	Percentage Glass collection	Percentage Paper collection	Percentage Plastic collection
2000	0.657	0.489	0.220
2001	0.678	0.517	0.269
2002	0.693	0.556	0.317

Note: The number of sample municipalities is 2951.

Table 3: Estimation result: Glass bottles

	mean	std	2.5%CI	97.5%CI
Dummy: possessing incineration	-0.159	0.214	-0.587	0.253
Dummy: possessing waste power generation	0.181	0.228	-0.26	0.641
Dummy: possessing RDF	0.439	0.443	-0.386	1.358
Dummy: possessing landfill solely	1.009	0.208	0.597	1.425
Dummy: sharing landfill	-0.007	0.167	-0.349	0.316
Landfill capacity (year)	0.128	0.238	-0.331	0.607
Waste generation (tons)	5.661	0.845	3.962	7.239
Wage rate	-1.754	1.273	-4.355	-0.01
Population density	-0.694	0.167	-1.025	-0.368
Proportion of contracting out	0.089	0.126	-0.163	0.329
Year 01	0.141	0.07	0.003	0.278
Year 02	0.259	0.075	0.113	0.409
α	2.009	1.257	0.355	4.583
ξ^2	10.306	1.049	8.445	12.432
ρ_0	0.386	0.022	0.341	0.429
ρ_1	0.409	0.022	0.361	0.451
ρ_2	0.433	0.021	0.39	0.472

Table 4: Estimation result: Paper containers

	mean	std	2.5%CI	97.5%CI
Dummy: possessing incineration	0.006	0.223	-0.436	0.44
Dummy: possessing waste power generation	0.169	0.243	-0.317	0.655
Dummy: possessing RDF	-0.713	0.541	-1.773	0.359
Dummy: possessing landfill solely	1.047	0.212	0.621	1.467
Dummy: sharing landfill	-0.243	0.177	-0.605	0.096
Landfill capacity (year)	-0.129	0.202	-0.532	0.26
Waste generation (tons)	3.154	0.624	1.955	4.418
Wage rate	-1.571	1.318	-4.246	0.26
Population density	-0.261	0.177	-0.615	0.084
Proportion of contracting out	0.534	0.132	0.271	0.79
Year 01	0.24	0.062	0.119	0.363
Year 02	0.585	0.069	0.451	0.72
α	0.619	1.295	-1.092	3.231
ξ^2	13.648	1.253	11.395	16.365
ρ_0	0.293	0.023	0.249	0.338
ρ_1	0.318	0.022	0.273	0.362
ρ_2	0.367	0.021	0.324	0.407

Table 5: Estimation result: Plastic containers

	mean	std	2.5%CI	97.5%CI
Dummy: possessing incineration	-0.193	0.232	-0.652	0.26
Dummy: possessing waste power generation	-0.145	0.229	-0.603	0.315
Dummy: possessing RDF	-2.298	0.693	-3.673	-0.973
Dummy: possessing landfill solely	1.142	0.207	0.738	1.551
Dummy: sharing landfill	0.063	0.174	-0.29	0.397
Landfill capacity (year)	0.123	0.205	-0.283	0.529
Waste generation (tons)	0.69	0.432	-0.173	1.532
Wage rate	-1.893	1.236	-4.395	-0.208
Population density	-0.244	0.168	-0.58	0.082
Proportion of contracting out	0.244	0.105	0.025	0.446
Year 01	0.475	0.08	0.322	0.634
Year 02	0.994	0.093	0.814	1.175
α	-0.633	1.226	-2.213	1.855
ξ^2	10.268	1.08	8.339	12.475
ρ_0	0.317	0.025	0.269	0.364
ρ_1	0.312	0.024	0.265	0.358
ρ_2	0.388	0.022	0.345	0.433