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The effect of Unit Based Pricing on Municipal Solid Waste and Recycling

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Abstract

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The purpose of this study is to analyze the effect of the UBP prices on household waste emissions by using the household waste collection service demand function. This study focused on the effect of the UBP policy by considering local government's pricing method. Using the aggregate data of waste disposal behavior and socioeconomic factors from 2007 to 2016, the municipal solid waste and recycling collection demand function are estimated. The spatial dependence and the condition of the policy were analyzed to correct the endogeneity of the UBP price. The results of this study are as follows: The garbage bag price is influenced by the prices of contiguous regions and is determined by the economic and politic factors of the local government. The local garbage bag prices are likely to mimic each other among the adjacent regions and affected by the political decision. As a result of waste and recycling collection demand function, the price elasticities on solid waste and recycled collections were −0.2897 and 0.2828 respectively, indicating the inelastic behavior to the UBP. In addition, when the garbage bag price increases, the decrement of the solid waste is greater than the increment of the recycling collection, so the total amount of household waste collection is expected to decrease as the UBP price increases. It means that even if the price of a waste bag is raised, there exists a price effect that reduces the total waste collection. The policy implications of this study are as follows. When the UBP price increases, the increment of recycling is less than the reduction of waste, so an additional recycling policy needs to be accompanied to encourage recycling. In addition, it is required to increase the bag price for each local government considering the similarity in price among neighboring regions. In particular, it is necessary to provide a guideline for the provincial level governments to intervene by providing concrete and realistic guidelines for the price selection of contiguous local governments to raise the UBP.

Keyword : Municipal Solid Waste, Recycling, Unit Based Pricing, Spatial Panel Model, Waste collection demand function

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Chapter 1. Introduction

Solid waste disposal problems have become major environmental issues in Korea. The government has focused the “Not In My Back Yard (NIMBY)” phenomena and lack of landfill sites due to the rapid growth of household expenditure and waste since early 1990s, implementing the Unit Based Pricing system (UBP) as an economic incentive in 1995. The UBP in Korea is volume-based system with plastic bag and Local government imposes it at the county level. Under the UBP, households are required to purchase special plastic bags authorized by local government to dispose of solid waste. Since there is no disposal fee for recyclable waste in Korea, households can save money by separating out recyclable and reducing solid waste. As a result, the UBP is a kind of pigouvian tax, which impute the marginal social cost of waste dumping to waste passer. Household generating waste pays the costs of collection and disposal through purchasing garbage bag, which achieves “Polluter pays principle” (Hong, 1991).

Unlike the other country where each local government decides to implement the UBP and choose the type of the UBP, Korea has applied the UBP to all regions at the same time. Although the local government does not decide whether to implement the UBP, the UBP in each county are considered as individual policy instruments. Governments decide the unit price of garbage bag and the way they collect and disposal the solid waste and recyclable materials. According to Lee *et al.* (2006), the UBP policy in Korea is established by local governments in each county and the price of garbage bag is based on the collection and disposal fee. Local governments decide the target residential burden rate[①] to set unit price according to the UBP guideline by Ministry of Environment. The guideline implies that target residential burden rate can be differ from each region and provincial government can adjust the county unit price. Thus, the garbage bag price is not determined independently at the county level, the governments set the policy in consideration of the policies of the neighbor region and the provincial governments to which the county belongs. However, studies that does not consider the policy selection assumed the policy is identical and independent. Even some studies pointing out that the regional difference of policy can affects the effect of UBP, but they did not control the local policy characteristic(Seo and Jeong, 2007; Jeong *et al.*, 2007).

This study attempts to analyze the effect of the UBP on solid waste disposal and recycling behavior. We estimated the household demand function of waste and recycling collection on county level to analyze whether the UBP reduce waste quantities and increase recycling. Especially, we focused on the possibility of endogeneity policy choices in the unit price of garbage bag. If state policy making is purposeful action, responsive to economic and political condition within the region, then it may be necessary to identify and control for the forces that lead policies to change if one wishes to obtain unbiased policy effect (Besley and Case, 2000). We tried to control not only the political and economic condition, but also spatial correlation between neighbor regions in the price decision. The Spatial Two-stage least squares (S2SLS) is used to estimate the

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① Residential burden rate is the ratio of the garbage bag sales revenue to the cost of collecting, transporting, and disposal solid waste. Local governments decide the price of garbage bag by presuming the target residential burden rate.

solid waste and recycling collection demand function.

The remainder of this thesis is divided in 3 chapters. Chapter 2 reviews the residential solid waste collection services in Korea and the literature on the waste and recycling collection demand function. Chapter 3 presents the model specification including data, variable, methodology and we suggest the estimation results at the end of this chapter. Chapter 4 summarizes the result and conclusion.

Chapter 2. Literature Review

In This chapter, we considered the theoretical background of the UBP and municipal waste market, and reviewed the literature discussing the effect of the relationship between the UBP and municipal waste.

2.1. Theoretical Background

The theoretical framework for analyzing household waste discharges is largely divided into traditional consumption theory and household production theory. In Jenkins' (1993) traditional consumption theory, municipal waste is a by-product that is proportional to consumption, and household utility is determined only by consumption, without taking into account the disutility of waste emissions. On the other hand, in household production theory, households produce consumer goods that increase utility by using actual purchased goods, time and waste emissions (Richardson and Havlicek, 1974). In household production theory, consumption is determined by other economic characteristics, including waste emissions, so a more flexible form of the utility function can be assumed than traditional production theory, from which a direct waste collection service demand function can be derived. In this study, the household production model of Kinnaman and Fullerton (2000) was used to derive the waste demand function. Household produces consumer goods that increase utility by using actual purchased goods, time and waste emissions. In household production theory, consumption is determined by other economic characteristics, including waste emissions, so a utility function can have various factors other than consumption. In this study, household production model of Kinnaman and Fullerton (2000) was used to derive the waste demand function

Household production theory assumes that each community region consists of N homogeneous and identical households. Households consume a single commodity and waste is produced through consumption. Consumption goods are a type of composite produced with waste emissions and purchased goods that are closely related to waste emissions. Municipal waste is divided into household waste discharged in a UBP bag and recycled material, illegal dumping and illegal incineration. Households choose which of the three ways to discharge their waste depends on their socioeconomic preferences and opportunity costs. Under these assumptions of the household production theory, the utility function of households is set as Equation (2−1).

$$u = u[c, g, r, i; \alpha]$$

2−(1)

$Subject\ to$

$$m = c + p_g g + p_r r + p_i i$$

c: Consumption goods

g: Municipal waste collected in UBP bag

r: Recycled material

i: Illegal dumping

α : Socio−economic variables

m: Income

p : Price of the waste

We can find the indirect demand function of household waste, recycling and segregation, and illegal dumping through the first order conditions in maximizing the utility of households. In this process, it is assumed that household waste disposal methods are simultaneously determined, therefore, the amount of waste discharged by each disposal method is determined at the same time.

$g = g(p_g, p_r, p_i, m; \alpha)$

$r = r(p_g, p_r, p_i, m; \alpha)$

$i = i(p_g, p_r, p_i, m; \alpha)$

In equation 2−(2), 2−(3) and 2−(4), p_g, p_r, p_i are the price for municipal waste, recycling and illegal dumping respectively. The price or cost of recycling and illegal dumping are not market price, and consist of opportunity costs, including time and effort for unobservable segregation, storage and transportation of waste. Since these opportunity costs of recycling and the costs of illegal dumping are unknown, the pricing equations for each treatment method are assumed to be a function of UBP bag prices and income, and other socioeconomic factors. We can use the socioeconomic variables as proxy variables of the opportunity cost. In other words, the socioeconomic factor α is a surrogate variable for unobserved recycling and illegal dumping. Finally, by subtracting the waste price equation from the waste indirect demand function, a regional aggregate demand function can be derived for each waste treatment method.

$p_g = p_g(P_g, P_r, M; \alpha)$ 2−(5)

$p_r = p_r(P_g, P_r, M; \alpha)$ 2−(6)

$p_i = p_i(P_g, P_r, M; \alpha)$ 2−(7)

When the UBP is not implemented, households generally do not pay for waste emissions and the government pays 100% of waste disposal costs. Since there is no cost to the waste emitters, the waste collection service price is zero, and the waste emissions are Q^* as shown in Figure 1. Equilibrium in the waste discharge service market is achieved when the waste discharge price is equal to the marginal cost of waste disposal, where waste emissions (Q_1) and prices are optimal for waste collection service providers. However, it is practically difficult for the government to set the marginal cost associated with the waste discharge by household, so that the local government calculates the total cost of the total waste emissions and sets the average cost (AC) divided by household. By imposing the average cost (Q_2) on the UBP bag price, emissions can be reduced from the Q^* point before the UBP point to the Q_2 point. However, in Korea, the price of the garbage bag is less than half of the garbage bag price (P_2) according to the actual average cost of waste disposal. In other words, since the price of the garbage bag is set at Q_2according to the actual average cost of waste disposal. In other words, since the price of the garbage bag is set at P_3 based on AC' rather than AC, the amount of waste is Q_3. In this case, the policy effect is as much as the area of ΔAQ_3Q^*.

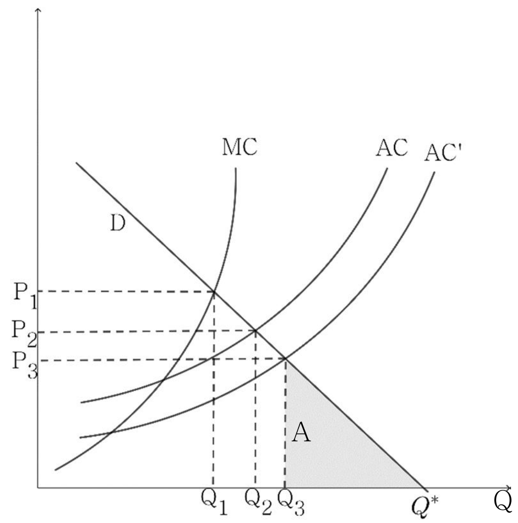

Figure 1 Municipal Solid Waste collection market under the UBP

2.2. Empirical Studies of the UBP

The UBP works as a price incentive to burden the pollutants with the social costs generated by household waste dumping, thereby suppressing waste emissions and encouraging recycling and separate discharge. According to Hong (2015), the positive effects of the UBP are divided into the reduction of general waste emission and the encouragement of separating recyclables. We reviewed several studies that address the effect of UBP in terms of three issues in this research; 1) Identifying the effect of the UBP on solid waste disposal and recycling behavior of household, 2) Assessing the appropriate explanatory variables as proxies of opportunity cost and environmental activism which not revealed in the market, 3) correction of policy bias with the endogeneity in UBP.

Several studies have tried to investigate the total effect of UBP based on the estimated elasticities. Hong (1999) analyzed waste and recycling demand function in Korea at the household level, suggesting the feedback effect of UBP between recycling and solid waste. They insisted that the amount of recycling exceeds the amount of solid waste because of feedback effect, thus the total solid waste can be increased with the feedback effect. However, they also discussed that once the UBP is in place, the price increase did not appear to have a significant effect on the recycling. Similarly, Hong (2015) implied that that reduction in the demand for non-food solid waste collection is mainly achieved by increasing the amount of recyclable and food wastes collected. This implies that price incentive effects are offset by the decrease in source reduction efforts because of feedback effects resulting from the increase in recycling, food waste separation.

However, some studies suggested that the reduction of solid waste exceeds the increment of recycling, which implies the reduction of total solid waste, which implies the negative effect of the UBP. Kinnaman and Fullerton (2000) analyzed that the implementation of a $1 user fee could decrease the quantity of garbage by 412 pounds per person, year but increase recycling by only 30 pounds per person per year. Linderhof *et al.* (2001) also suggested that the price effect for solid waste is much larger than the effect for recycling with household level data. In addition to these studies, Dijkgraaf and Gradus (2004) and Tsai and Sheu (2009) considered whether the excess of waste actually disappeared by UBP. They have doubted the idea that the consumption propensity are changed to reduce solid waste reduced due to implementing UBP. They rather suggested the possibility of the alternative such as illegal dumping or illegal incinerating. Dijkgraaf and Gradus (2004) analyzed the empirical evidence with the total solid waste demand model and guessed that a large part of the reduction in unsorted waste is due to illegal dumping. Although Kinnaman and Fullerton (2000) suggested the probability of waste reduction at the source, or by composting, but it is common that the reduction of total waste implies the possibility of illegal dumping.

Another major issue to analyze the effect of the UBP is to investigate the proxy variable of the opportunity cost and collection cost with socioeconomic variables. It is important to control the opportunity cost to waste separation and collection with other explanatory variables. Several studies focusing on recycling demand under the UBP tried to find not only the substitution price effect, but also the environmental and social factors that affect to recycling separation. Several studies used the population density as a proxy for transportation and congestion cost to solid waste disposal. Kinnaman and Fullerton (2000) hypothesize that there are more opportunities for illegal dumping are provided in areas where population density is very high or very low: urban areas with commercial dumpsters and rural areas with remote spots for dumping. Even though the empirical evidence was not shown when using the squared population density, but other studies have used this idea to determine the relationship between population density and the solid waste. In general, higher population densities result in higher landfill reserves, higher collection costs, and higher UBP price, resulting in lower emissions, but at the same time, increased recycling. On the other hand, there is a claim that the higher population density is urbanized than that of other regions, leading to an increase in waste emissions along with the consumption of goods (Hage and Soderhold, 2008; Usui, 2008).

Besides, several variables such as dwelling type, education, the age of population and education are used to control the waste disposal and recycling. In terms of the age rate, the more the elderly population, the more the emission of waste increases. The more elderly population, the less time is needed to put their household waste into the UBP garbage bag or to separate them (Dijkgraaf and Gradus, 2009; Tsai and Sheu, 2009). However, there is the contrary idea of the relation between solid waste and age composition. Seo and Jeong (2007) and Linderhof *et al.* (2001) suggested that the elderly population are not familiar with the waste disposal system of UBP, which increases the possibility of illegal dumping, ignoring the UBP. Similarly, the higher the level of education in the region, the higher the rate of adaptation to the UBP, which leads to less potential for illegal dumping, resulting in increased overall waste emission (Tsai and Sheu, 2009; Hong, 1999). On the contrary, the higher the level of education, the higher the opportunity cost required to separate waste. Because of this increment of opportunity cost, the separation of recycling might be reduced (Reschovsky and Stone, 1994, Kinnaman and Fullerton, 2000).

The dwelling type and other supplemental waste management program such as curbside recycling are considered in several studies. According to Hage and Soderhold (2008), multi-unit dwelling makes it difficult to extend UBP to residents of these dwellings. Similarly, Hong (2015) implied that the multi-unit dwelling reduces the solid waste and recycled material. It is impossible to incinerate the waste, and to separate and store the recyclables in the house for a while in multi-unit houses. Due to the poor space conditions, there may be a low interest in the separation of recycled materials, and it is likely that it is not easy to monitor and punish the waste even if it is dumped at the collection point without putting the waste in the garbage bag. The other supplemental waste management program such as curbside recycling and type of UBP also affects to the solid waste disposal and recycling and several studies investigated the relation between the UBP effect and other program(Isely and Lowen, 2007; Kinnaman and Fullerton, 2000; Huang *et al.*, 2011).

Finally, recent studies are focused on the endogeneity issue of the UBP policy. The endogeneity issue in analyzing the UBP effect closely related to the probability of local policy selection issues and several studies suggested the evidence of policy selection bias. Kinnaman and Fullerton (2000) controlled the endogeneity in discrete choice of local government to implement UBP for the first time. They suggested the probability of biased estimators in both ways, understated or overstated. Both the positive effect on recycling and the negative effect on garbage could be overstated if the estimation processes omit an unobservable variable such as the environmental awareness of the community. The omitted variable might increase the probability that a community implements green policies such as a user fee and curbside recycling program, increase the observed quantity of recycling by these environmentally aware citizens, and consequently reduce the observed quantity of garbage. On the other hand, the effects of such policies could be understated if the likelihood of implementing these local policies is a positive function of the quantity of garbage collected in the community.

Based on the idea of Fullerton and Kinnaman (2000), Isely and Lowen (2007) found that there is also the possibility that the difference in the UBP price can adversely affect the waste propensity. Usui (2008) also analyzed the discrete choice of local government of UBP with Tobit model to control the measurement error in recycling demand function. Allers and Hoeben (2010) controlled the price decision with spatial and time lag of price. They insisted that the introduction of a tax is more likely if neighboring jurisdictions have already introduced such a tax and policy interaction in waste pricing may be the result of political yardstick competition or information dissemination. De Jaeger *et al.* (2012) considered the municipalities mimicking the unit price of waste, so that the possibility of the consumers' response to price in neighboring municipalities. Huang *et al.* (2011) and Usui and Takeuchi (2013) also considered the probability of endogeneity in UBP variable, but they found no evidence of endogeneity, suggesting that the bias could be alleviated by fixed effect of panel model.

Table 1 Studies of Solid Waste and Recycling Demand Function

Demand Function	Research	Data Unit	Socioeconomic Variables	Correction of Endogeneity
Municipal Solid Waste	Huang *et al.*(2011)	Aggregate	household size, education, population density	property tax rate, capital improvement plan
	Mazzanti *et al.*(2012)	Aggregate	population density, value added, tourism	Spatial lagged effect
	De Jaeger *et al.* (2012)	Aggregate	Population density, dwelling type, tourism	Spatial lagged price
Recycling	Reschovsky and Stone(1994)	Household	storage space, awareness of recycling, education, working time	–
	Hage and Soderhold(2008)	Aggregate	urbanization rate, population density, city size, dwelling type	–
	Usui(2008)	Aggregate	share of recycling material, UBP type, disposal cost, landfill rate	Implementing UBP and price choice
Municipal Solid Waste and Recycling	Hong *et al.*(1993)	Household	female's wage, education, race	–
	Hong (1999)	Household	female's wage, income, household size, education, value of time	–
	Linderhof *et al.*(2001)	Household	dwelling type, household size, age, weather	–
	Kinnaman and Fullerton(2000)	Aggregate	recycling program, retirement, average family size, education, population density	Implementing UBP and price choice
	Dijkgraaf and Grdus(2009)	Aggregate	environmental activism, retirement, household size, population density	–
	Tsai and Sheu(2009)	Aggregate	income, education, environmental expenditure	–
	Allers and Hoeben(2010)	Aggregate	population density, race, age, ideology	Spatial, time lagged price
	Usui and Takeuchi(2013)	Aggregate	population density, income, share of recycling	–
	Hong(2015)	Aggregate	GRDP, population density, dwelling type	–
	Dijkgraaf and Grdus(2015)	Aggregate	number of household, population density, collection operator	Environmental activism with implementing time

In conclusion, there are several implications to consider when analyzing the solid waste and recycling demand function. First, comparing the price elasticities of municipal solid waste and recycling is required to verify the positive effect of the UBP. The large gap between the elasticities can be a suspicion of illegal dumping, even if the UBP reduces solid waste and encourage recycling. If the substitution elasticity on recycling is much less than the price elasticity on solid waste, the loss of solid waste may be due to increment illegal dumping. It is unlikely that the amount of consumption sensitively reflects the level of UBP, the decrement of solid waste is expected to be shifted to recycling comparatively. However, several studies pointed out that there are large differences between the response of solid waste and recycling to UBP, which. The amount of illegal dumping cannot be observed, but the price elasticity on solid waste and recycling need to be compared simultaneously, not respectively, to analyze the positive effect of the UBP on the waste disposal behavior of household.

In addition, considering the endogeneity problem to analyze the effect of UBP is needed. The municipalities decided whether to implement the UBP or not and they also choose the unit price for waste collection. The endogeneity in UBP can be summarized as the spatial and temporal dependence of price determination and the environmental activism with other waste policies such as curbside recycling program. In Korea, the municipality arbitrary determine the UBP price which can make the policy effect biased. Therefore, this study analyzes the endogeneity problem due to local government's price decision and the price elasticity on waste after correcting endogenous bias.

Chapter 3. Analysis

This chapter presents model specification and results of the solid waste collection demand function. We reviewed the waste collection market and emission of solid waste and recycling in Korea, considered the data and variables for the research models and specified waste and recycling model and reviewed the methodology. Finally, we discussed the estimation results.

3.1. Unit Based Pricing System in Korea

After UBP was implemented in 1995, the ministry of environment has made an effort to make the garbage bag price reasonable in terms of tipping cost. The bag prices of each county are set based on the average disposal cost per weight and the cost include collection and transportation cost, waste disposal costs for landfill and incineration and bag production cost. Local governments compose the price with target residential burden rate, which is uniquely set by the government. The guidance of the UBP has been revised several times to make the local garbage bag price reasonable. In 1999, the goal was to raise the residential burden rate to 100% by 2003. In 2004, the target residential burden rate was relaxed to 60% by 2008. However, most regions did not achieve the target residential burden rate, thus the ministry of environment changed the guideline once again in 2009.

The pricing method has not been changed, on the other hand, the policy to achieve the goals has changed over time. Before 2008, the guideline sets the target residential rate individually based on administrative type. However, the recent guideline began to stand out the role of the provincial government to raise the UBP price of county−level region. The guide recommends that province level government can encourage adjustment of bag price to each county level government based on PPP. The provincial government can manage the large price gap among counties since it can make discordance between the place where the garbage is discharged and the place where the garbage is collected. Based on this guideline, the metropolitan cities have begun to apply the same price to county regions. In table 2, after the guideline abandon the target residential burden rate, the overall residential burden rate has been decreased. However, after the explicit target residential burden rate disappeared, the residential burden rate has been recovered better in metropolitan cities where the UBP price are unified than provincial region where the local government set the UBP price individually.

Table 2 The residential burden rate

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Seoul	61.0	66.0	58.5	53.0	47.3	40.0	39.0	46.5	48.0	54.9
Busan	79.0	77.0	74.2	60.0	68.6	41.0	48.8	34.7	49.0	58.7
Daegu	61.0	58.0	53.2	56.0	43.1	37.0	37.6	25.4	31.0	46.1
Incheon	59.0	58.0	49.8	40.0	40.6	34.0	33.1	36.3	42.0	49.4
Gwangju	51.0	46.0	38.8	57.0	43.2	29.0	35.1	39.8	43.0	46.2
Daejeon	86.0	76.0	66.8	59.0	49.4	38.0	36.5	34.8	43.0	41.0
Ulsan	84.0	74.0	65.4	65.0	65.9	54.0	56.3	58.0	53.0	60.5
Gyeonggi	31.0	29.0	28.3	28.0	24.6	25.0	23.1	25.3	26.0	27.3
Ganwon	25.0	23.0	17.8	23.0	21.1	18.0	14.1	17.5	18.0	18.3
Chungbuk	21.0	23.0	17.6	20.0	18.7	14.0	14.9	12.9	21.0	22.1
Chungnam	18.0	17.0	17.3	14.0	14.3	13.0	11.9	13.9	23.0	15.8
Jeonbuk	13.0	15.0	12.7	16.0	12.2	11.0	12.6	13.8	30.0	17.6
Jeonnam	16.0	16.0	12.3	12.0	12.2	11.0	10.2	13.5	32.0	15.3
Gyeongbuk	16.0	17.0	15.1	16.0	12.7	13.0	12.9	15.6	9.0	13.9
Gyeongnam	49.0	44.0	37.8	35.0	32.6	29.0	30.1	28.1	46.0	37.2
Jeju	33.0	30.0	24.9	28.0	11.8	15.0	14.2	11.8	13.0	15.3
Metripolitan city	68.7	65.0	58.1	55.7	51.2	39.0	40.9	39.4	44.1	51.0
Province	24.7	23.8	20.4	21.3	17.8	16.6	16.0	16.9	24.2	20.3

3.2. Model Specification

(1) Waste and Recycling Collection Demand Function

A regional aggregate demand function for each waste treatment method – solid waste, recycled material, illegal dumping – can be derived by subtracting the waste price equation from the waste indirect demand function. Among aggregate demand function, the illegal dumping function is not considered in this study due to lack of illegal dumping data.

As reviewed in chapter 2, the aggregate solid waste and recycling collection demand functions includes the price of UBP for solid waste, the price of recycled material, income and socio-economic variable. In general the existence of the recycling program is used for price of recycling in demand function for market price. However, in Korea, as with the UBP, Curbside program of recycling has been implemented in all regions. Therefore, the curbside recycling program cannot be used as the recycling price in the waste collection market. This study constructed the demand function without considering the recycling price in the market and used the UBP price for the market price. A linear econometric specification of solid waste and recycling collection equations in region i time t are:

$$G_{it} = \alpha_0^g P_{it}^g + \alpha_1^g M_{it} + X_{it}^g \alpha^g + \epsilon_{it} \quad 3-(1)$$

$$R_{it} = \alpha_0^r P_{it}^g + \alpha_1^r M_{it} + X_{it}^r \alpha^r + \epsilon_{it} \quad 3-(2)$$

G : The Municipal Solid Waste collected in garbage bag

R : The Recycled Material collected by the curbside program

P^g : The UBP garbage bag price

M : Regional Income

X^g : Explanatory variables for the municipal solid waste

X^r : Explanatory variables for the recycled material

(2) Spatial Autocorrelation Test

The ministry of environment (2018) and De Jaeger *et al.* (2012) implies that the local municipalities mimic the UBP price each other. If the county level government in Korea determines the garbage bag price considering that of neighboring municipalities, the spatial relation of price can make the UBP price endogenous and the estimator becomes biased and loses consistency. Therefore, we tested the existence of spatial dependence of the UBP bag price with spatial weighted matrix.

The spatial weight matrix is a matrix that expresses the spatial relations between objects to be analyzed, and is divided into a contiguity matrix and an inverse distance matrix. The contiguity matrix assigns weights of 1 to adjacent areas and 0 to non-adjacent areas, depending on whether the local governments are adjacent to each other. Contiguity matrices are further divided into look contiguity and queen contiguity, depending on how local contiguity is given (Lee *et al.*, 2006). The look contiguity matrix assumes the area where the edges abut as the adjoining area, whereas the queen contiguity matrix assumes the adjoining area as well as the corners. The inverse distance matrix sets the inverse of the inter-region distance as a weight under the assumption that the farther the distance is, the less the spatial dependency between regions is. In this research, we select the queen contiguity matrix as a spatial weight matrix to investigate the spatial neighboring correlation of bag price[②].

② The spatial neighboring relation in the garbage bag price might be seen in regions that share boundaries on administrative boundaries, not just geographically close areas since the provincial government has important role to adjust the bag price. We tested the first-queen matrix, the second-

Using queen contiguity matrix, we tested the spatial dependence of the garbage bag price with “Global Moran's I”. The Global Moran’s I is a representative index for measuring spatial autocorrelation. It is an index indicating whether a distribution pattern of a particular phenomenon in a space has a certain order or randomly. The global peony index has a value between −1 and 1, and has a value greater than 0 when there is an association through similar characteristics among contiguous regions and represents positive spatial autocorrelation. On the other hand, if the associations are based on different characteristics, they have a value less than zero and show negative spatial autocorrelation. The table 3 shows that the Moran’s I of the garbage bag price is highly close to 1, which implies the UBP price is highly spatially correlated. In addition, there are significant positive spatial correlation in municipal solid waste and recycling collection.

Table 3 The Global Moran's I statistics

	The garbage bag price(20l)	Municipal Solid Waste	Recycling
2007	0.7327***	0.3147***	0.1921***
2010	0.7238***	0.4528***	0.1431***
2013	0.7321***	0.5111***	0.1552***
2016	0.6558***	0.3542***	0.2067***

'***' 0.001 '**' 0.01 '*' 0.05 '·' 0.1

The global Moran’s I does not presents the regional pattern of the garbage bag price, but Local Indicators of Spatial Autocorrelation (LISA) shows the cluster pattern of the price. Using the Local Getis-Ord G indicator, the pattern of hot spot and cold spot of garbage bag price can be distinguished. In terms of Getis-Ord G, cold spots with low bag prices were found in the

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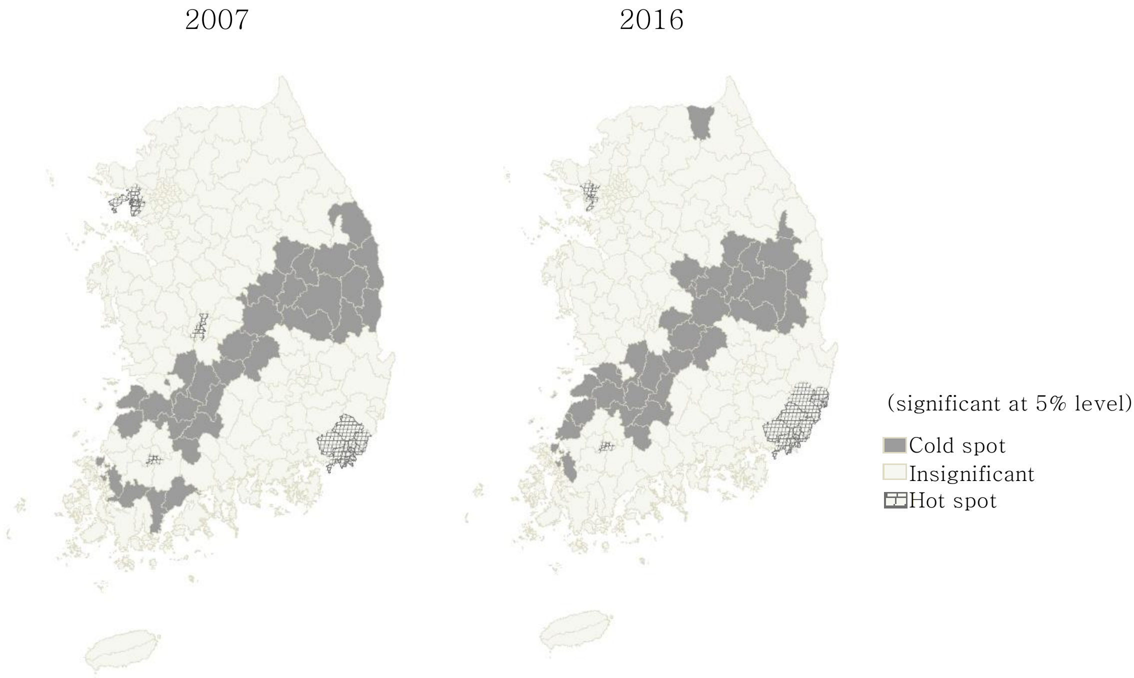
queen matrix, the third-queen matrix and the inverse distance matrix with *ex-post* AIC statistics, and select the first-queen matrix as a result.

neighboring regions of Gyeongsang, Chungcheong, and Jeolla provinces—the central region —and hot spots with high bag prices were found regions in Gyeongnam, Busan— the southeast region— and Seoul Metropolitan Area. In particular, cold spots in mid-central regions, which are geographically contiguous, are concentrated except metropolitan city among the regions. It means that the spatial dependences analyzed above are different depending on the administrative districts and the characteristics of metropolitan municipalities, not just the geographical conditions of adjacent municipalities. Not only the geographical condition makes the bag price endogenous, but also the characteristic of municipalities affects the UBP price. Therefore the spatial dependency of the UBP price among adjacent regions and the price decision in each municipality are considered to correct the endogeneity of the UBP price.

Figure 2 The Getis-Ord G map



(3) Endogeneity Test

When the equation has omitted variable bias, the independent variable is endogenous and the OLS estimation of the equation generally results in inconsistent estimators. It is likely that the endogeneity of the local policy in the public service sector can affect the policy effect since the purpose of policy can contradict the economic condition of public service (Besley and Case, 2000). Thus, it needs to correct the possibility of endogeneity to estimate the policy effect precisely. In this research, the UBP price can be endogenous since the municipalities' policy making is purposeful action. This study considered the instrumental variables for the UBP price as a policy action of local governments. Supposing the endogeneity of the UBP price, the endogeneity of independent variables can be tested by Durbin-Wu-Hausman test (Hausman specification test)③. Hausman specification test hypothesizes that the price variable is exogenous, and if the statistics rejects the null hypothesis, the price is endogenous.

$$H = (\beta_1 - \beta_0)'(Var(\beta_1) - Var(\beta_0))^{-1}(\beta_1 - \beta_0),$$
$$H \sim \chi^2(K-1) \qquad 3-(3)$$

The H statistics rejects the exogeneity of the price variable for both solid waste and recycling equation. Thus, the demand function using the instrumental variables is analyzed to investigate the effect of the UBP.

Table 4 Durbin-Wu-Hausman statistics

	H statistics
Solid Waste equation	192.8523***
Recycling equation	1452.584***

③ The Hausman specification test is *Post-hoc* to test the endogeneity in explanatory variable. Thus the estimators using fixed effect model and the estimators of 2 stage least squares are used for the endogeneity test

(4) Methodology

In this research, we need to deal with simultaneous equations of solid waste collection and the UBP bag price. We tried to control the unobserved effect of panel data set with two way fixed effect and random effect. We then tested for the model specification with Hausman's chi square statistics.

We focused on the endogeneity bias in the UBP bag price. When the price variable is not exogenous, the error in the price can make measurement error, which makes the biased estimator of the effect of the UBP. Thus we estimated the price equation, then the local policy choices are estimated as functions of observable exogenous variables. We then use the predicted values for these policy variables to correct for possible endogeneity in the garbage and recycling demand equations using 2 Stage Least Squares (2SLS).

$$Y = \beta_0 + X_1\beta_1 + X\beta + e$$
$$e \sim N(0,\sigma^2),\ E(X_1 e) \neq 0,\ E(Xe) = 0 \qquad 3-(4)$$

If X_1 is correlated with error, the instrumental variable that highly correlated with X_1 but not e is needed to estimate 2SLS. The instrumental variable (Z_1) is correlated with X_1, but not correlated with e ($\mathrm{cov}(Z_1 X_1) \neq 0, \mathrm{cov}(Z_1 e) = 0$). In first stage, the equation of X_1 is estimated with instrumental variables and explanatory variables. Then, predict $\widehat{X_1}$ to estimate the original equation.

$$X_1 = \pi_0 + Z_1\pi_1 + X\pi + v \qquad 3-(5)$$
$$\widehat{X_1} = \widehat{\pi_0} + Z_1\widehat{\pi_1} + X\hat{\pi} \qquad 3-(6)$$

The $\widehat{X_1}$ satisfies the exogeneity condition ($E(\widehat{X_1}e) = 0$), thus in second stage the original equation substituting X_1 with $\widehat{X_1}$ is estimated to get consistent estimators.

$$Y = \beta_0 + \widehat{X_1}\beta_1 + X\beta + u, \qquad 3-(7)$$
$$u = e + \beta_1 v$$

To estimate the demand function, this study considered the spatial autocorrelation of solid waste and recycling. The spatial panel model has been used in many recent studies since it was first introduced by Elhorst (2003). It is likely to use spatial panel model to analyze regional policies that the intra−region relation affects the policy. The spatial panel data is characterized as observations with spatial autocorrelation are repeatedly examined over several periods of time. That is, the time unit is added to the general spatial econometric model. The generalized form of the spatial panel model is as follows.

$$Y_t = \alpha_0 + \lambda W_{NT} Y_t + X_t \beta + W_{NT} X_t \theta + u_t$$
$$u_t = \rho W_{NT} u_t + \epsilon_t \qquad 3-(8)$$
$$W_{NT} = I_T \otimes W_N$$

Spatial panel model can be divided into “Spatial Autoregressive Model (SAR)”, “Spatial Error Model (SEM)”, and “Spatial Autocorrelation Model (SAC)” depending on which term has a spatial effect. The SAR reflects spatial dependence of dependent variables using spatial lag variable. In SAR, the λ means the spatial effect of dependent variable. On the contrary, the SEM reflects spatial autocorrelation on error term, which cannot be seen in variables. In SEM, the spatial effect implies the spatial heterogeneity, and the error term is divided into error term with spatial heterogeneity and error term without. Where ρ represents the spatial effect in error term, like the spatial error model. The

SAC is combined model of SAR and SEM, which controls both spatial dependency and spatial heterogeneity by considering spatial lag term in dependent variable and error term.

In this study, the spatial panel model is used only for the 1st stage of 2SLS, the price equation. To get consistent estimators, the SAR model is only used for price equation. In the SAR model, the explanatory variable of the adjacent region may change according to the change of the limit of the explanatory variable of the region, which may affect not only my region but also neighboring regions. In other words, if the spatial dependence exists and the price function is estimated using the spatial panel model, the coefficient cannot be interpreted as the marginal effect by itself, and additional model development is needed to derive the marginal effect. The direct and indirect effects were calculated using the estimated coefficients of the price function.

$$
\begin{aligned}
y_t &= (I_n - \rho W)^{-1}\iota_n\alpha_0 + (I_n - \rho W)^{-1}(X_t\beta + WX_t\theta) + (I_n - \rho W)^{-1}\epsilon_t^* \\
&= [\textstyle\sum_{k=1}^{K} S_k(W)x_k]_t + (I_n - \rho W)^{-1}\alpha_0 + (I_n - \rho W)^{-1}\epsilon_t^* \\
S_k(W) &= (I_n - \rho W)^{-1}(I_n\beta_k + W\theta_k)
\end{aligned}
\qquad 3-(9)
$$

ϵ_t^* includes the fixed effect of model. To find the marginal effect of the kth explanatory variable of region i at the specified time t, the partial derivatives of x_k on both hand sides are as follows.

$$
[\frac{\partial y}{\partial x_k}]_t = S_k(W) = (I_n - \rho W)^{-1}\begin{bmatrix} \beta_k & w_{12}\theta_k & \cdots & w_{1n}\theta_k \\ w_{21}\theta_k & \beta_k & \cdots & w_{2n}\theta_k \\ \vdots & \vdots & \vdots & \vdots \\ w_{n1}\theta_k & w_{n2}\theta_k & \cdots & \beta_k \end{bmatrix} \qquad 3-(10)
$$

The direct effect represents the effect of the independent variable of the local area on the dependent variable, and the feedback effect includes the influence of the independent variable of the local area returning to the local area through the adjacent area. That is, the feedback effect can be estimated by subtracting the direct effect from the effect of the explanatory variable of the model. The indirect effect is the spatial spillover effect that the independent variable of the adjacent area affects the area. The indirect effect is calculated by subtracting the direct effect from the total effect.

$$M(k)_{total} = \iota_n{}' S_k(W) \iota_n \quad 3-(11)$$

$$M(k)_{direct} = n^{-1} tr(S_k(W)) \quad 3-(12)$$

$$M(k)_{feedback} = M(k)_{direct} - \beta_k \quad 3-(13)$$

$$M(k)_{indirect} = M(k)_{total} - M(k)_{direct} \quad 3-(14)$$

(5) Data

This research focused on solid waste and recycled material collection of 229 counties from 2007 to 2016. We set up a balanced panel data set through aggregating regions where the administrative district has changed in 2007 to 2016. In this study, we used various data sources to consider solid waste and recycled material collection, details of the UBP and socioeconomic variables. The amounts of waste and recycling collection are from annual "National municipal waste generation and disposal report". The garbage bag prices, tipping costs and residential burden rates, which are the key variables to indicate the regional UBP policy, come from "Unit Based Pricing system report" . In addition, we reviewed the other socio economic data such as "Regional account" at county level, "Statistics city yearbook of Korea" , "Survey of the economically active population" .

Table 5 lists the total quantity of municipal solid waste, recycled materials and the price of 20 liter garbage bag for municipal waste. The trend of average garbage bag price shows it has been rarely increasing from 421 won per 20 liter bag in 2013 to 427 won per bag. The residential burden rate, which indicates the ratio of disposal cost to bag selling revenue also decreased from 36% in 2007 to 23% in 2007, slightly increasing after 2014. Decrement of residential burden rate and little increment of price shows that waste collection and disposal costs burdened by municipalities has increased, incurring increment of financial burden.

In terms of the solid waste and recycled material quantity, it seems that there is no relationship between the change of solid waste and that of recycling. The amount of solid waste per capita and day increased from 301g/person, day in 2007 to 337g/person, day in 2008, gradually decreased until 2010 to 327g/person, day, and again, slightly increased until 2016 to 377g/person, day. Similarly, the amount of recycled material per capita and day also increased from 259g/person, day in 2007 to 269g/person, day in 2009, but decreased to 240g/person, day in 2016. Therefore, it is necessary to estimate the demand function in order to analyze the effect of the UBP, considering a little change in waste volume and the financial burden due to little price increment. In addition, Lee *et al.* (2013) pointed out that local governments, which determine the bag price, are passive in raising the bag price due to concern about illegal dumping and inflation. Thus, the uncertain trend of bag price and solid waste could be because of the contrived way government sets garbage bag price.

Table 5 Waste collection in Korea

Year	Garbage bag price (20l/won)	Residential burden rate (%)	Municipal solid waste (g/day, person)	Recycled material (g/day, person)
2007	414.78	35.92	301.17	259.50
2008	421.91(+7.13)	35.87(−0.05)	337.98(+36.98)	256.10(−3.4)
2009	422.33(+0.42)	32.19(−2.97)	333.57(−4.41)	269.38(+13.28)
2010	423.27(+0.94)	30.23(−1.96)	327.22(−6.35)	255.01(−14.37)
2011	425.06(+1.79)	28.92(−1.31)	340.43(+13.21)	242.78(−12.23)
2012	424.52(−0.54)	26.34(−2.58)	344.71(+4.28)	248.63(+5.85)
2013	427.79(+3.27)	26.00(−0.34)	343.85(−0.85)	235.77(−12.86)
2014	432.36(+4.57)	23.09(−2.91)	355.05(+11.2)	241.47(+5.7)
2015	446.04(+13.68)	31.37(+8.28)	352.36(−2.69)	231.48(−9.99)
2016	463.59(+17.55)	34.98(+3.61)	377.30(+24.94)	240.12(+8.64)

(The difference from previous year in parenthesis)

(6) Variables

The variables for the municipal waste and recycling collection demand function are selected to estimate the set of demand function. For the dependent variables, the average daily amount of municipal waste and recycled material per person are used. As independent variables, variables which are able to reflect the opportunity cost of waste disposal and recycling, regional environmental activism and regional municipal waste policy are selected. For the garbage bag price, average bag price per liter is used. Several studies in Korea used the price of 20l bag since it is one of the major public charges that relates the consumer price selected by the ministry of interior and safety. However, some municipalities do not produce 20l garbage bag, and even within the region, the price are not linearly proportional to volume. In addition, the bag price changes by 10 won, which can be categorized variable that are not proper as explanatory variables. Thus the average price of bag per liter is used, which are transformed into a real term with the consumer price index.

For the explanatory variable, Gross Regional Product is used as income variable, which is the sum of total value added and net production tax. However, the data from 2007 to 2009 of Seoul and Gyeonggi, Gwangju are missing. Therefore, we predicted the missing GRP with local income tax and residential income tax by the method of Kim (2010)[④] and transformed into real term with the producer price index. Population density, the average number of Collection per week, the ratio of household who lives in multi-unit dwelling houses such as apartment and education rate are used as

④ The GRP estimation formula used in the study is as follows

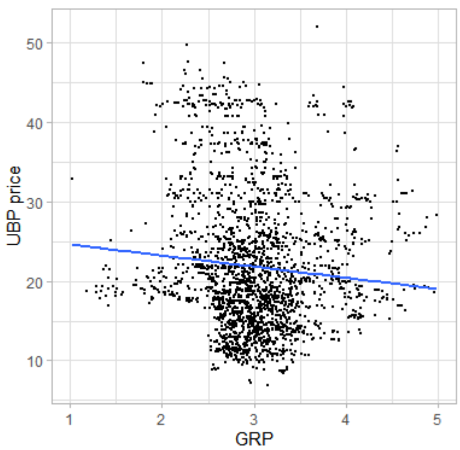
$$\mathrm{GR}P_j = \mathrm{GR}P_i \times \frac{Income\ Tax_{ji}}{\sum_i Income\ Tax_{ji}}$$

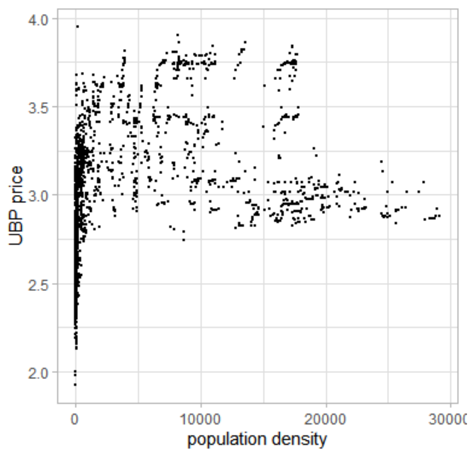
proxy variables of opportunity cost to waste disposal and recycling. Especially, households in Korea are not charged for recycling under the identical curbside program. The price of the UBP in recycling demand function shows the substitution price elasticity with UBP bag price, but it is not sufficient to explain the recycling behavior of household, which supports of proxy variables. Thus, the average number of collections

per week is used to control the cost of recycling.

In addition, we analyzed the changes of the price effect on solid waste and recycling by other explanatory variable. The GRP and population density is likely to affects the solid waste and recycling collection of household since they are closely related to the opportunity cost such as transportation and storage. In the figure 3, the relation between the GRP and the UBP price seems to be negative, otherwise, the relation between the population density and the UBP price is not continuous. Thus we tested the slope change of the UBP price on solid waste and recycling with the GRP and population density and considered the discrete relation between population density and the bag price. Based on prior data−mining, the slope changes of the UBP price on recycling with GRP is used to

Figure 3 The correlation between the UBP and socioeconomic variables





explain recycling function. On the other hand, the slope changes of the price on solid waste has investigated where the population density is less than 54.7, the 11% quantile of population density, and more than 14743.6, the 89% quantile of population density, using it as an explanatory variable of solid waste function.

To consider the endogeneity of the UBP price, the instrumental variables that explain the price selection are needed. In this study, we focused on the price selection provided by the ministry of environment (2018). According to the ministry of environment (2018), there could exists the price mimicking among the neighboring region, as shown in 3.2.(2). The county level government in Korea adjust UBP bag price with the target residential burden rate considering its community and neighbor region and they are affected by the province they belong to. In addition, the UBP price is calculated with the residential burden rate and tipping cost. The tipping cost explains the economic factor of the UBP price, otherwise, the residential burden rate covers the political condition in the UBP price. To correct the endogeneity of the UBP bag price, we considered some proxy variables of the tipping cost and the residential burden rate. In the case of economic factor, the lagged tipping cost, the lagged quantity of solid waste and recycling are considered[⑤]. In terms of political condition, the UBP guideline shows that each municipalities set their own target residential burden rate to set the UBP price, however, the target residential burden rate cannot be officially accessed. Thus the lagged residential burden rate and the lagged financial independence

⑤ We tested the lagged tipping cost, the lagged quantity of solid waste and recycling for 1, 2 year respectively to find strong instrumental variable. As a result, the lagged tipping cost for 1 year is used as a strong instrument variable that controlled the endogeneity best.

are examined to control the political action of the UBP price and the lagged financial independence has been chosen as strong instrument variable. To sum up, the spatial, time lagged price for the effect of neighboring region, the lagged tipping cost for the economic factor and the lagged financial independence for the political selection are used as instrument variables. The table 6 shows the description of

Table 6 Variable Description

Variable	Definition	Unit
Endogenous variables		
Solid Waste	Municipal solid waste collected in UBP garbage bag	g/ person, day

overall variables in the UBP price, solid waste, recycling equation.

Recycle	Recycled material	g/ person, day
Garbage bag price	Real price of UBP garbage bag	Won/ liter
Exogenous variables in solid waste collection equation		
Income	Real GRP per capita	Million won/person
Population density	Population to area	Person/km^2
Education	Percentage of the population possessing a bachelor or more degree	%
Collection	Weighted average number of collection	Time/week
Dwelling type	The ratio of household who lives in mansions and apartment	%
High population density	1 if the population density is bigger than 14743.6, 0 otherwise	Dummy
Low population density	1 if the population density is smaller than 54.7, 0 otherwise	Dummy
Instrumental variables in the UBP price equation		
Tipping cost	Municipal solid waste tipping cost	Million won
Financial independence rate	The ratio of tax income to total budget	%

3.3. Results

(1) Descriptive Statistics

Table 7 shows the basic statistics. In this study, the data of city and county level region from 2007 to 2016 in Korea are used. The amount and range of solid waste are generally bigger than that of recycled materials. The ranges of waste and garbage bag price 2049 g/person, day and 820 won respectively, implying the waste generation varies largely depending on independent variables. The financial independence rate, one of the instrumental variables of the UBP price, is less than 30% on average, which shows the price decision of the regional government might give a burden on local financial condition.

	Obs	Min	Mean	Max	S.D.	Unit
Solid Waste	2290	44.5	411.4	2093.1	227.5	g/person, day
Recycled material	2290	5.7	251.0	1619.7	175.2	g/person, day
20l bag price	2290	80	429.90	900	169.79	Won
Unit bag price	2290	6.85	21.76	52.10	8.44	Won/liter
GRP	2290	1.91	32.07	2957.13	105.62	Million won
Population density	2290	19.11	4013.56	29104.38	6382.93	명/km2
Education	2290	4.42	19.26	50.51	6.72	%
Dwelling	2290	4.39	16.51	37.49	7.60	%
Collection	2290	1	3.21	6	1.78	Number
Tipping cost	2290	462	20,910	2,505,728	118,796	Million won
Financial independence	2290	6.40	27.34	90.50	15.46	%

Table 7 Summary Statistics

(2) The UBP Price function

In first stage regression of the UBP price function, the spatial and time lagged price, the time lagged financial independence, the time lagged tipping cost are used as the instrumental variables. The instrumental variables have a positive effect on the garbage bag price in each equation (Table 8). The positive effect of spatial and time lagged price shows that if the neighboring municipalities raise the unit price, the likelihood of a municipality raising the garbage bag price may well be higher. It implies that the contiguous municipalities mimic the garbage bag price one another.

This policy interaction in UBP pricing might be the result of political competition (Allers and Hoeben, 2010). The local governments are reluctant to raise the garbage bag price more than the neighboring regions since it can cause the illegal dumping and complaints from the residents. It implies that the price decision of a region is similar to that of neighboring regions, with the spatial correlation of the bag price in chapter 3.2.

In addition to the spatial dependence of price, the effect of financial independence is larger than that of tipping cost in both equations. It implies that the effect of politic selection is larger than that of economic condition. The low residential burden rate and the low effect of financial independence supports that the local governments set the garbage bag price based on their politic condition, which implies that despite the increase in the amount of waste and tipping costs, there is a pressure to raise the UBP price due to politic condition, including the condition of neighboring regions.

Table 8 First stage regression of the UBP price

	Solid Waste		Recycling	
(Intercept)	1.6118	***	1.5700	***
	(0.0951)		(0.0965)	
Instrumental Variable				
Wlog(p_{t-1})	0.2067	***	0.2000	***
	(0.0264)		(0.0276)	
log(FI_{t-1})	0.1429	***	0.1464	***
	(0.0092)		(0.0091)	
log($tcost_{t-1}$)	0.0871	***	0.0955	***
	(0.0062)		(0.0066)	
County−level Attributes				
log(M)	−0.0059		−0.0071	
	(0.0053)		(0.0071)	
Edu	0.1532		0.0019	
	(0.1002)		(0.0017)	
Comm	0.0942	***	0.0859	***
	(0.0271)		(0.0259)	
Collection	−0.0126		0.0049	
	(0.0122)		(0.0061)	
high popdens	0.5001			
	(0.3058)			
low popdens	−0.0443			
	(0.2750)			
popdens			0.000002	
			(0.0000)	
Wlog(p_{t-1})*high popdens	−0.0336	***		
	(0.0498)			
log(FI_{t-1})*high popdens	−0.1269	***		
	(0.0337)			
log($tcost_{t-1}$)*high popdens	−0.0509			
	(0.0235)			
Wlog(p_{t-1})*low popdens	0.0219	*		
	(0.0082)			
log(FI_{t-1})*low popdens	0.0828	*		
	(0.0210)			
log($tcost_{t-1}$)*low popdens	0.1149	***		
	(0.0214)			
Wlog(p_{t-1})*log(M)			−0.0002	
			(0.0003)	
log(FI_{t-1})*log(M)			−0.0002	
			(0.0001)	
log($tcost_{t-1}$)*log(M)			−0.0001	
			(0.0001)	
region fixed effects	Yes		Yes	
year fixed effects	Yes		Yes	
Adjusted R^2	0.8247		0.8203	

(3) Municipal Solid Waste function

The table 10 shows the result of the municipal solid waste collection demand function. The LM test and the robust LM test for spatial lag and spatial error was performed (Table 9). For the municipal solid waste equation, the robust LM statistics for spatial lag and error are significantly positive. In addition, the −2logL in SAC is smallest, showing that the SAC model fits the data best. The spatial autocorrelation of the dependent variable(λ) and the spatial error term(ρ) in the SAC model are significantly 0.4708 and −0.3276 at the 5% level. The value of 0.4708 for the spatial lag parameter (λ) implies that when the average of the waste in the neighboring municipalities increases by 1 g, the price in municipality i increases by 0.4708g. It implies that the waste disposal behavior of household is spatially dependent among contiguous region.

Table 9 LM test of MSW

	χ^2 statistics
LM(lag)	133.82 ***
Robust LM(lag)	44.99 ***
LM(error)	109.20 ***
Robust LM(error)	20.37 ***

The UBP price effect on municipal waste function is significantly negative in fixed effect, 2SLS and spatial 2SLS model. The garbage bag price significantly reduces the waste collection. This coincides with the household production theory, which is the theoretical background of this study, and supports the theoretical argument that the amount of solid waste decreases as the garbage bag price increases. The overall price effects are inelastic, which coincides with previous estimates. In SAC model, the price effect is significantly −0.2722 at the 5% level, showing the inelastic impact of the UBP on MSW collection. The absolute value of the coefficient in the fixed effect model is smaller than that in 2SLS model, which implies the price effect has been understated before correcting price endogeneity. The likelihood of price decision is the positive function of the quantity of garbage. There exists the benefits of raising the UBP price for the large town with relatively large garbage emission has high price (Kinnaman and Fullerton, 2000).

The coefficient of GRP is significantly positive, which shows that households in affluent regions generates more solid waste. In SAC model, the income elasticity is significantly 0.1089 at the 5% level, and it supports that theoretical assumption of the relation between consumption and waste generation, since the production income is proportional to the consumption level of that region. In addition, the price effect varies depending on the population density. In the region with high population density, the space to store and recycling is not enough in congested region, and the price makes up a small part of the total cost of household for solid waste disposal than other region. Thus the households in dense region are more inelastic. However, the price effect in the small sized region with low population density is larger than other regions. The change of price elasticity is twice as large as that of other regions. It is likely that the transport cost in those regions is much larger than the dense region and the illegal dumping is easier than those regions due to lack of proper surveillance system. Thus, the large change of price elasticity implies not only the weak effect of the UBP in less dense regions but also the possibility of illegal dumping.

Among the socio-economic variables, the effect of the number of collections is significantly positive on waste collection, but it is not certain that the frequent collection makes more waste. The rate of high education also increases the waste collection demand in SAC model. It can be interpreted as the higher level of overall education, the easier tendency of adaptation to the UBP policy. As a result, the likelihood of illegal dumping is less than regions with low education.

In the spatial panel model, the coefficient cannot be interpreted as the marginal effect itself, as discussed in chapter 3.2. Therefore, the marginal effects of explanatory variables on solid waste collection are needed to be calculated. Table 11 shows the direct, feedback, indirect effect from the SAC model of each variable in municipal solid waste collection function. The sign of direct effect and indirect effect in all variables are same since the coefficient of the spatial lag term (λ) is positive. In the case of per capita income, the direct effect is 0.1214, the indirect effect is 0.0373 and the total effect is 0.1587. It means that the total waste increases by 0.1587% for income increasing by 1%. In other words, when 1% of income increases, the total collection of waste in the country increases by 0.1587%, of which the amount of waste in the region increases by 0.1214%, and the amount of waste in contiguous regions increases by 0.0373%. In addition, the feedback effect was 0.0031, which means that when income in one's region increases by 1%, income in adjacent regions increases due to spatial dependence, and the income effect increases by 0.0002% additionally in the region.

In the case of the garbage bag price, the direct effect is −0.2897% and the indirect effect is −0.0889%, so when the UBP price in the region is increased by 1%, the total waste is reduced by 0.3786% of which the amount of waste in the region decreases by 0.2897%, and the amount of waste in adjacent regions decreases by 0.0889%. In other words, the marginal effect of the price consists of 76% direct effects in the region and 24% indirect effects in contiguous regions.

Table 10 Municipal solid waste collection demand function

	Fixed effect	2SLS	SAR	SEM	SAC
(Intercept)	−0.9267 . (0.4815)	−0.5001 (0.4968)	−0.6964 * (0.2713)	−1.0381 *** (0.2868)	−0.3895 (0.2431)
log(P)	−0.3420 ** (0.1174)	−0.4678 *** (0.1256)	−0.2824 ** (0.1001)	−0.2903 ** (0.1050)	−0.2722 ** (0.0906)
log(M)	0.1722 *** (0.0425)	0.1652 *** (0.0422)	0.1183 *** (0.0119)	0.1219 *** (0.0125)	0.1089 *** (0.0108)
high popdens	−1.6908 * (0.8186)	−1.9996 * (0.8331)	−2.2501 *** (0.3346)	−2.2953 *** (0.3394)	−2.0466 *** (0.3177)
low popdens	−0.5267 (0.5663)	−0.9421 (0.7022)	1.1543 ** (0.3742)	1.0478 ** (0.3888)	1.2718 *** (0.3443)
edu	−0.1331 (0.6594)	−0.0951 (0.6537)	0.4238 . (0.2286)	0.3669 (0.2428)	0.4468 * (0.2026)
comm	−0.2258 (0.1956)	−0.1629 (0.1973)	−0.0684 (0.0660)	−0.0611 (0.0679)	−0.0729 (0.0611)
collection	0.3694 *** (0.0942)	0.3386 *** (0.0942)	0.1599 *** (0.0273)	0.1584 *** (0.0275)	0.1521 *** (0.0261)
log(P)*high popdens	0.0495 . (0.0255)	0.0589 * (0.0259)	0.0666 *** (0.0101)	0.0680 *** (0.0102)	0.0604 *** (0.0953)
log(P)*high popdens	0.1978 (0.1903)	0.3378 (0.2418)	−0.3979 ** (0.1397)	−0.3565 * (0.1446)	−0.4452 *** (0.1292)
λ			0.2542 *** (0.0258)		0.4708 *** (0.0434)
ρ				0.2286 *** (0.0292)	−0.3276 *** (0.0669)
region fixed effects	Yes	Yes	Yes	Yes	Yes
year fixed effects	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.3129	0.3264			
−2logL			−1768.05	−1799.64	−1749.63

The indirect effect of price is likely to be due to the fact that there is a spatial dependence on the bag prices due to the similarity of the UBP price, which can be interpreted as a spatial spillover effect due to similar pricing methods among neighboring regions.

Table 11 Marginal effect of MSW

	Direct	Feedback	Indirect	Total
log(P)	−0.2897	−0.0073	−0.0889	−0.3786
log(M)	0.1214	0.0031	0.0373	0.1587
high popdens	−2.3084	−0.0583	−0.7085	−3.0169
low popdens	1.1842	0.0299	0.3635	1.5477
edu	0.4348	0.0110	0.1335	0.5683
comm	−0.0702	−0.0018	−0.0216	−0.0918
collection	0.1641	0.0041	0.0504	0.2145
log(P)*high popdens	0.0683	0.0017	0.0209	0.0893
log(P)*low popdens	−0.4083	−0.0103	−0.1253	−0.5336

Using the effect of instrumental variables and the price elasticity, it is possible to predict the spillover effect of the price. First, when the price in the region increases by 1%, the MSW collection of that region will decrease by 0.2897%, and that of neighboring regions decrease by 0.0889%. A 1% increase in the bag price in the region reduces 0.3786% of the total solid waste, which is the size of marginal effect.

Second, the garbage bag price increases by 0.2067% when all prices of neighboring regions in the previous year increased by 1% each. Continually, the increment of the bag price in the region due to spatial spillover effect reduces the amount of solid waste in the region by 0.0598%, decreases 0.0183% in the neighboring areas, and decreases the amount of solid by 0.0015% in our region through other regions. Consequently, the 1% increase of the neighboring prices reduces the total solid waste emission by 0.0782%.

Finally, when financial independence increases by 1% − not 1% p− the bag price in the region increases by 0.1429% in the following year. Increasing the bag price in the region reduces the solid waste in the region by 0.0414%, a 0.0127% in neighboring regions, and a 0.0127% in our region across other regions. The 1% increase of financial independence reduces the total solid waste by 0.0541%.

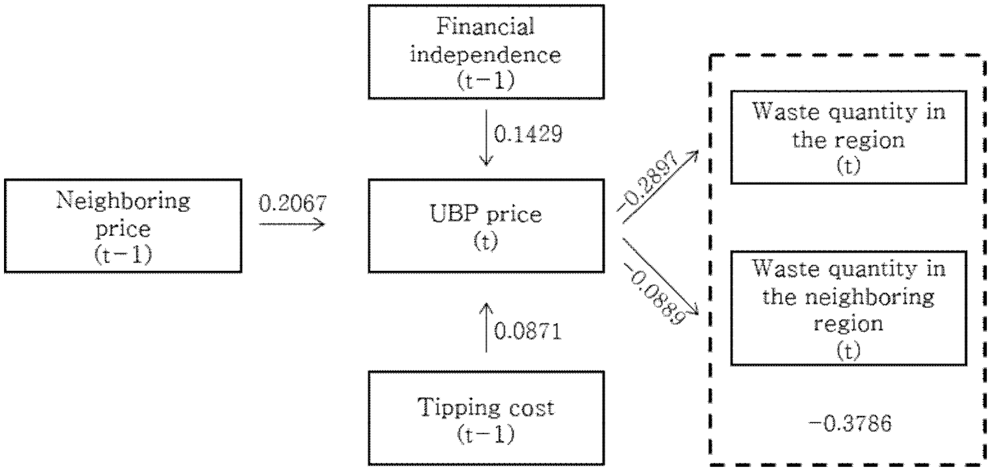


Figure 4 The spillover effect of MSW collection

(4) Recycled material function

The table 13 shows the result of the recycling demand function. The LM test and the robust LM test for spatial lag and spatial error was performed. For the recycling, the robust LM statistics for spatial lag and error are not significantly positive, only the LM statistics for spatial lag and error term are positive. In addition, the −2logL in SAC is smallest, showing that the SAC model fits the data best. The spatial autocorrelation of the dependent variable(λ) and the spatial error term(ρ) in the SAC model are significantly 0.3155 and −0.2472 at the 5% level. It implies that the recycling behavior of household is spatially dependent among adjacent region, same as the MSW demand function.

Table 12 LM test of recycling

	χ^2 statistics
LM(lag)	102.71 ***
Robust LM(lag)	3.23 .
LM(error)	100.82 ***
Robust LM(error)	1.33

The UBP price effect on recycling function is significantly positive in fixed effect, 2SLS, and weakly significant in spatial 2SLS models. The garbage bag price raises the amount of recycling. The overall price effects on recycling are also inelastic. In SAC model, the price effect is significantly 0.3125 at the 10% level, showing the inelastic impact of the UBP on recyclable materials collection. The coefficient in the fixed effect model is smaller than that in 2SLS model, which implies the price effect in recycling function is also understated before correcting the price endogeneity.

The coefficient of GRP is significantly positive, which shows that households in rich regions recycles more. In SAC model, the income elasticity is significantly 0.1271 at the 5% level, since the increase of consumption raises the recyclable materials too. In addition, the price effect varies by the income in recycling model. In every model, the interaction term of the bag price and income are significantly negative, which shows that the price elasticity decreases as income increases. The recycling behavior is related to the cost to separate materials and environmental activism of household. If the environmental activism affects the recycling behavior more than the opportunity cost of recycling, the recycling might be increased as the income increases. However, in this study, it is likely that the household concerned the size opportunity cost to recycle more than the environmental activism in Korea.

Among the socio-economic variables, the effect of population density is not significant and the size of the coefficient is not different from zero. When considering the slope dummy as the MSW collection function, it was not significant, unlike the MSW, which means the recycling behavior are not affected by the population density. In addition, unlike the MSW collection, the education level and the dwelling type significantly affect recycling behavior. The positive effect of the education level implies that the recycling separation behavior can be gotten by education. The negative effect of multi-unit dwelling type implies that the opportunity cost to separate and recycling materials is large when the household lives in apartments. The household who lives in multi-unit dwelling type are unlikely to having adequate space for sorting and storing recyclables (Ando and Gosselin, 2005).

Table 13 Recycling collection demand function

	Fixed effect	2SLS	SAR	SEM	SAC
(Intercept)	−4.7069 *** (0.7682)	−4.8073 *** (0.9024)	−2.1853 *** (0.5294)	−2.6719 *** (0.5400)	−1.3352 ** (0.4983)
log(P)	0.8568 *** (0.2347)	0.8951 ** (0.2704)	0.2806 . (0.1577)	0.3692 . (0.2007)	0.2850 . (0.1675)
log(M)	0.2044 . (0.1073)	0.2101 . (0.1144)	0.1522 *** (0.0316)	0.1648 *** (0.0321)	0.1271 *** (0.0300)
popdens	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)
edu	0.0660 ** (0.0221)	0.0495 . (0.0255)	0.0314 *** (0.0079)	0.0336 *** (0.0079)	0.0256 *** (0.0077)
comm	−0.5017 * (0.2525)	−0.6522 * (0.2714)	−0.5610 *** (0.1296)	−0.5914 *** (0.1309)	−0.4848 *** (0.1239)
collection	0.0064 (0.0277)	0.0150 (0.0281)	0.0500 . (0.0273)	0.0539 * (0.0273)	0.0397 (0.0269)
log(P)*log(M)	−0.0221 ** (0.0075)	−0.0165 . (0.0087)	−0.0107 *** (0.0027)	−0.0115 *** (0.0027)	−0.0087 *** (0.0026)
λ			0.1190 *** (0.0282)		0.3155 *** (0.0843)
ρ				0.1238 *** (0.0308)	−0.2472 * (0.1133)
region fixed effects	Yes	Yes	Yes	Yes	Yes
year fixed effects	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.0619	0.0696			
−2logL			−4989.71	−4991.19	−4987.08

Table 14 shows the marginal effect from the SAC model of variables in the recycling collection function. The sign of direct effect and indirect effect in all variables are same since the coefficient of the spatial lag term (λ) is positive. In the case of the garbage bag price, the direct effect is 0.2828% and the indirect effect is 0.0357%, when the UBP price in the region is increased by 1%, the total recyclable material is increased by 0.3185% of which the amount of collected recyclables in the region increases by 0.2828%, and the amount of collected recyclables in contiguous regions increases by 0.0357%. In other words, the marginal effect of the price consists of 89% direct effects in the region and 11% indirect effects in contiguous regions. The indirect effect of price can be interpreted as a spatial spillover effect due to similar pricing methods among neighboring regions, same as MSW.

Table 14 Marginal effect of recycling

	Direct	Feedback	Indirect	Total
log(P)	0.2828	0.0022	0.0357	0.3185
log(M)	0.1534	0.0012	0.0194	0.1728
Popdens	0.0000	0.0000	0.0000	0.0000
Edu	0.0316	0.0002	0.0040	0.0356
Comm	−0.5653	−0.0044	−0.0715	−0.6368
Collection	0.0504	0.0004	0.0064	0.0568
log(P)*log(M)	−0.0108	−0.0001	−0.0014	−0.0122

The prediction using the spatial spillover effect and the instrumental variable can also be applied to recycling behavior. First, when the price in the region increases by 1%, the recycling collection of that region decreases by 0.2828%, and that of neighboring regions decrease by 0.0357%. A 1% increase in the bag price in the region encourages 0.3185% of the total recycling, which is the size of marginal effect in table 11.

Second, the garbage bag price in the region increases by 0.2000% when all prices of neighboring regions in the previous year increased by 1% each. Continually, the increment of the bag price in the region due to spatial spillover effect increases the recycling collection in the region by 0.0565%, 0.0071% in the neighboring areas, and 0.0004% in the region through other regions. Consequently, the 1% increase of the neighboring prices increases the total recycling collection by 0.0637%.

Finally, when financial independence increases by 1% the bag price in the region increases by 0.1464% in the next year. Increasing the bag price in the region increases the recyclables in the region by 0.0414%, a 0.0052% in neighboring regions, and a 0.0003% in our region across other regions. The 1% increase of financial independence reduces the total solid waste by 0.0466%. Figure 5 shows the overall spillover effect discussed in this study.

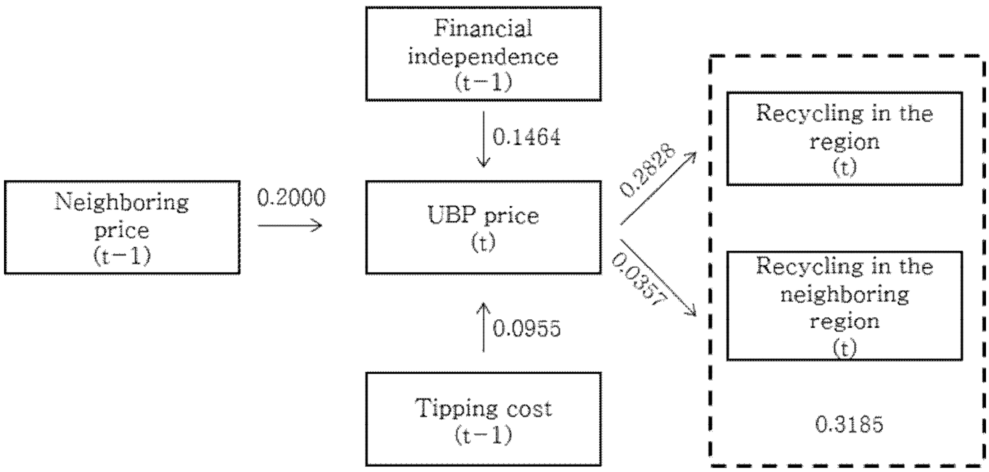


Figure 5 The spillover effect of recycling collection

In addition to spatial spillover effect, the elasticity of price on solid waste and recycling collection needs to be compared to analyze the net effect of the UBP, as discussed in the literature review. The elasticity of MSW is larger than that of recycling, and the MSW quantity changes based on average quantity in 2016 is larger than that of recycling. It implies that the UBP affects solid waste more than recycling. It is likely that the total waste collection is reduced due to the UBP, which shows the net positive effect. On the other hand, the loss of the total waste implies that the possibility of illegal dumping cannot be ruled out.

Table 15 The changes of waste collection

	Direct	Feedback	Indirect	Total
MSW elasticity	−0.2897	−0.0073	−0.0889	−0.3786
Recycling elasticity	0.2828	0.0022	0.0357	0.3185
Change of MSW	−137.6	−3.5	−42.2	−179.7
Change of recycling	70.3	0.5	8.9	79.2

(%, g/person, day)

Chapter 4. Conclusion

The UBP system is recognized as one of the successful waste management policy in Korea, but the studies on the effect of the UBP are relatively insufficient. This study analyzed the effects of the Unit-Based Pricing system on the solid waste and recycling collection. In particular, this study focused on the endogeneity of local pricing and spatial correlation of waste collection market. Using National Waste Generation and Disposal Status” and “Unit Based Pricing system report” from 2007 to 2016, the spatial panel 2SLS model was estimated for solid waste and recycling collection demand function. The spatial correlation in the garbage bag price and the amount of solid waste and recycling collection were investigated and the endogeneity in the garbage bag price was tested.

As a result, the UBP reduces the solid waste and encourages the recycling. Also, the spatial spillover effect exists in the UBP price which shows the likelihood of the price mimicking among the neighboring regions. Including the spatial effect, the price selection is affected by the financial independence and the endogenity of the UBP price understated the price effect since the price itself is the function of disposal behavior and policy selection. After correcting the endogeneity bias and the spatial dependence on the solid waste and recycling collection, the price elasticity on solid waste and recycling are significantly inelastic. In addition, the price effect on solid waste is larger than that on recycling, thus the total amount of waste still decreases when price and the amount of recycling are raised.

The main contribution of this study is that it provides the policy implications by correcting the endogeneity of price selection. According to the guidelines of the ministry of environment, Korea encouraged to set the appropriate garbage bag price based on the type of administration and the size of the region in order to realistically raise the garbage bag price. However, that guideline has not adequately achieved the target price level. In this study, it is investigated that not the type of region, but the spatial condition affects the price level. The local governments are likely to be hindered to raise the garbage bag policy due to the low price of neighboring regions. Thus, it is required to make the waste management policy considering the spatial relation on the price. Particularly, the role of provincial level government to set the price is needed to be considered more important to raise the garbage bag price appropriately. In fact, most regions where the prices are high enough to cover the tipping cost have selected the price that the provincial level government suggested since 2010. However, the provincial government does not actively engage in the pricing system of the region where the price is generally low. Therefore, it is necessary to emphasize the role of the provincial level government on pricing is required to make the price appropriate and get the better UBP effect on solid waste and recycling.

Bibliography

Aalbers, Rob F. T. and Herman R. J. Vollebergh (2008), “An Economic Analysis of Mixing Wastes.” Environmental and Resource Economics, 39: 311–30.

Allers, Maarten A. and Corine Hoeben (2010), “Effects of Unit−Based Garbage Pricing: A Differences−in−Differences Approach”, *Environmental and Resource Economics,* 45(3): 405–28.

Ando, Amy W. and Anne Y. Gosselin (2005), “Recycling in multifamily dwellings: does convenience matter?”, *Economic inquiry*, 43(2): 426−438.

Bartelings, Heleen and Thomas Sterner (1999), “Household Waste Management in a Swedish Municipality: Determinants of Waste Disposal, Recycling and Composting.” *Thomas Environmental and Resource Economics*, 13:473–91.

Bel, Germà and Raymond Gradus (2016), “Effects of Unit−Based Pricing on Household Waste Collection Demand: A Meta−Regression Analysis”, *Resource and Energy Economics*, 44: 169–82.

Besley, Timothy and Anne Case (2000), “Unnatural Experiments? Estimating the Incidence of Endogenous Policies.” *The Economic Journal*, 110: 672−694.

Callan, Scott J, Janet M Thomas and Bentley College (2006), “Analyzing Demand for Disposal and Recycling Services: A Systems Approach”, *Eastern Economic Journal,* 32(2): 221–40.

Chen, C. C. (2010), “Spatial Inequality in Municipal Solid Waste Disposal across Regions in Developing Countries.” *International Journal of Environmental Science and Technology,* 7(3):447–56.

De Jaeger, Simon, Johan Eyckmans, Stefan Van, and Tom Verbeke (2012), *Waste demand in the context of waste price mimicking*, Hub Research Papers.

Dijkgraaf, Elbert and Raymond Gradus (2004), “Cost Savings in Unit−Based Pricing of Household Waste. The Case of the Netherlands”, *Resource and Energy Economics*, 26(4): 353–71.

__________________________________(2009), “Environmental Activism and Dynamics of Unit-Based Pricing Systems”, *Resource and Energy Economics*, 31(1): 13–23.

Gradus, Raymond, Elbert Dijkgraaf and Mattheus Wassenaar (2014), “Understanding Mixed Forms of Refuse Collection, Privatization and Its Reverse in the Netherlands”, *International Public Management Journal,* 17(3):328–43.

Hage, Olle and Patrik Söderholm (2008), “An Econometric Analysis of Regional Differences in Household Waste Collection: The Case of Plastic Packaging Waste in Sweden”, *Waste Management* 28(10): 1720–31.

Hong, Seonghoon (1999), “The Effects of Unit Pricing System upon Household Solid Waste Management: The Korean Experience”, *Journal of Environmental Management*, 57: 1–10.

Hong, Seonghoon, Richard M. Adams and H. Alan Love (1993), “An Economic Analysis of Household Recycling of Solid Wastes: The Case of Portland, Oregon”, *Journal of Environmental Economics and Management,* 25(2): 136–46.

Houtven, George L. Van and Glenn E. Morris (2006), “Household Behavior under Alternative Pay-as-You-Throw Systems for Solid Waste Disposal”, *Land Economics* 75(4): 515.

Huang, Ju-chin, John M. Halstead and Shanna B. Saunders (2011), “Managing Municipal Solid Waste with Unit-Based Pricing: Policy Effects and Responsiveness to Pricing”, *Land Economics* 87(4): 645–60.

Ichinose, Daisuke, Masashi Yamamoto and Yuichiro Yoshida (2015), “The Decoupling of Affluence and Waste Discharge under Spatial Correlation: Do Richer Communities Discharge More Waste?”, *Environment and Development Economics 20*, (2):161–84.

Isely, Paul and Aaron Lowen (2007), “Price and Substitution in Residential Solid Waste”, Contemporary Economic Policy 25(3): 433–43.

Jenkins, Robin R., Salvador A. Martinez, Karen Palmer and Michael J. Podolsky (2000), "The Determinants of Household Recycling: A Material Specific Analysis of Unit Pricing and Recycling Program Attributes", *Resources of the Future*, 45(2): 294–318.

Kevrekidou, Maria (2016), "Exploring the Public Views Concerning the Introduction of 'Pay –As– You– Throw' Waste Management Systems in Greece", *International Hellenic University*.

Kim, Geum Soo, Young Jae Chang and David Kelleher (2008), "Unit Pricing of Municipal Solid Waste and Illegal Dumping: An Empirical Analysis of Korean Experience", *Environmental Economics and Policy Studies*, 9(3): 167–76.

Kinnaman, Thomas C and Don Fullerton (2000), "Garbage and Recycling with Endogenous Local Policy", *Journal of urban economics,* 48: 419-442.

Lakhan, Calvin (2015), "Evaluating the Effects of Unit Based Waste Disposal Schemes on the Collection of Household Recyclables in Ontario, Canada", *Resources, Conservation and Recycling,* 95:38–45.

Leao, Simone, Ian Bishop and David Evans (2004), "Spatial–Temporal Model for Demand and Allocation of Waste Landfills in Growing Urban Regions." *Computers, Environment and Urban Systems*, 28(4):353–85.

Lee, Misuk, Hyunhong Choi and Yoonmo Koo (2017), "Inconvenience Cost of Waste Disposal Behavior in South Korea", *Ecological Economics,* 140: 58–65.

LeSage, J. and Pace, R. K (2009), *Introduction to spatial econometrics,* Chapman and Hall/CRC.

Linderhof, Vincent, Peter Kooreman, Maarten Allers and Doede Wiersma (2001), "Weight–Based Pricing in the Collection of Household Waste: The Oostzaan Case", *Resource and Energy Economics*, 23(4): 359–71.

Mazzanti, Massimiliano, Anna Montini and Roberto Zoboli (2009), "Municipal Waste Generation and the EKC Hypothesis New Evidence Exploiting Province-Based Panel Data", *Applied Economics Letters,* 16(7):719–25.

Morris, Glenn E. and Duncan M. Holthausen (1994), "The Economics of Household Solid Waste Generation and Disposal", *Journal of Environmental Economics and Management*, 26(3): 215-34.

Reschovsky, James D. and Sarah E. Stone (1994), "Market Incentives to Encourage Household Waste Recycling: Paying for What You Throw Away", *Household Waste Recycling*, 13(1):120–39.

Richardson, Robert A. and Joseph Havlicek (1978) "Economic Analysis of the Composition of Household Solid Wastes", *Journal of Environmental Economics and Management*, 5(1):103–11.

Strathman, James G., Anthony M. Rufolo and Gerald C. S. Mildner (1995), "The Demand for Solid Waste Disposal", *Land Economics*, 71(1):57–64.

Tsai, Tsung Hsiu and Sheng Jang Sheu (2009), "Will Unit-Pricing Enhance Recycling?", *International Journal of Sustainable Development and World Ecology,* 16(2):102–8.

Usui, Takehiro (2008), "Estimating the Effect of Unit-Based Pricing in the Presence of Sample Selection Bias under Japanese Recycling Law", *Ecological Economics,* 66:282–88.

Usui, Takehiro and Kenji Takeuchi (2014), "Evaluating Unit-Based Pricing of Residential Solid Waste: A Panel Data Analysis", *Environmental and Resource Economics*, 58: 245-71.

Wright, Christopher (2012), "Essays on the Economics of Municipal and Household Solid Waste Disposal and Recycling", *University of New Hampshire.*

김종희(2010), "GRDP (지역내 총생산) 추정을 통한 지역 간 경제력 격차 분석", *지방행정연구*, 24(1), 207-235.

박완규(2010), "지방자치단체의 경제력 격차에 대한 분석", *지역연구,* 26(4): 75-101.

서재호 및 정광호(2007), "가격유인을 활용한 폐기물 감량화 정책효과 분석

–쓰레기 종량제를 중심으로”, *한국정책학회보*, 16(4): 147-73.

엄영호, 신가원 및 장용석(2014), “지방정부 음식물쓰레기 종량제 봉투 가격결정의 공간상호작용 분석 서울시 자치구를 중심으로”, *한국도시행정학회 학술발표대회 논문집*, 103-124.

오용선(2006), “쓰레기종량제도의 환경개선효과에 관한 비판적 평가”, *한국정책학회보*, 15(2): 245-68.

이성우, 윤성도, 박지영 및 민성희(2006), *공간계량모형응용,* 박영사.

이창로 및 박기호(2013), “인근지역 범위 설정이 공간회귀모형 적합에 미치는 영향”, *대한지리학회지,* 48(6): 978–993.

이희선, 신경희, 조공장, 한상운, 금현 및 양은모(2013), *종량제 생활폐기물 처리의 배출자 부담원칙 확대 적용 방안*, 환경정책평가연구원.

정광호, 서재호 및 홍준형(2007), “쓰레기 종량제 정책효과 실증분석: 광역시도를 중심으로”, *한국행정학회보*, 41(1): 175-201.

환경부(2018), *쓰레기 수수료 종량제 시행지침*

홍성훈(2015), “종량제 봉투 가격이 생활폐기물, 음식물쓰레기, 재활용품 수거서비스 수요에 미치는 영향”, *자원환경경제연구*, 24(4): 747-61.

국문초록

폐기물 종량제가 생활폐기물과 재활용 배출에 미치는 영향

본 연구의 목적은 가계가 배출하는 생활폐기물 수거 서비스 수요함수를 사용하여 생활폐기물 종량제 봉투 가격이 생활폐기물 배출에 미치는 영향을 분석하는 것이다. 본 연구에서는 지역정부의 가격 설정 방식을 고려하여 종량제 정책의 효과를 분석하였다. 환경부에서 발간한 2007년부터 2016까지의 '전국폐기물 발생 및 처리현황'과 '쓰레기 종량제 현황'을 사용 하여 생활폐기물 종량제 배출량, 재활용 분리수거량의 수요함수를 추정하였고 가격 설정의 내생성을 고려하여 가격의 공간 종속성과 정책적 요인을 분석하였다. 분석의 결과는 다음과 같다, 종량제 봉투 가격은 공간적으로 인접한 지역의 가격에 영향을 받으며 폐기물 수거서비스의 시장의 경제적 요인과 행정적인 요인에 의해 가격이 결정된다는 것을 확인하였다. 종량제 정책의 가격 효과를 분석한 결과, 이웃 지역의 봉투 가격이 서로 영향을 미친다는 것을 확인하였다. 또한 가격 설정 방식의 유사성으로 인해 폐기물과 재활용 배출에 공간 종속성이 존재한다는 것을 밝혔다. 종량제 수거량과 재활용 수거량의 가격탄력성은 각각 −0.2897, 0.2828으로 종량제 봉투가격에 대해 비탄력적으로 반응하는 것으로 나타났다. 또한 종량제 봉투 가격이 인상할 때 종량제 봉투 수거량의 감소 분이 재활용 수거량의 증가분보다 커 종량제 봉투 가격 인상에 따라 전체 생활폐기물 수거량이 감소할 것으로 예상되었다. 이는 폐기물 봉투 가격을 인상하더라도 가계의 전체 폐기물 배출이 줄어드는 가격 효과가 존재한다는 것을 의미한다. 본 연구의 정책적 함의는 다음과 같다. 종량제 봉투 가격이 인상될 때 재활용의 증가가 쓰레기 감소량보다 적기 때문에 재활용을 권장하기 위해 추가적인 재활용 정책이 수반될 필요가 있다. 또한 종량제 봉투

가격 인상이 요구될 때, 환경부는 주민부담률의 현실화를 근거로 지방자치단체에게 가격을 인상하도록 촉구하지만, 이를 행정적 구분에 의거하여 각 행정 단위마다 가격 인상의 개선을 다르게 요구하여 적절한 가격 인상이 이루어지지 않았다. 따라서 인접지역간의 가격의 유사성이 있다는 것을 고려하여 가격 인상의 지침을 마련하는 것이 필요하다. 특히 종량제 봉투 가격 인상을 위해 광역자치단체가 인접한 기초자치단체의 종량제 봉투 가격에 대한 구체적이고 현실적인 지침을 마련하여 개입하는 것이 필요하다.

Keyword : **생활쓰레기, 재활용, 생활폐기물 종량제, 공간패널모형, 폐기물 수거 수요함수**

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