Assessing Effects of Unit-Based Pricing on Household Waste Reduction Focusing on COVID-19 Period in Japan

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Abstract

This study aims to identify the effectiveness of municipal unit-based pricing (UBP) system on household waste reduction with a focus on COVID-19 period in Japan through a panel data analysis targeting 770 cities for 2013-2022. The study targets both simple unit-pricing (SUP) and two-tiered pricing (TTP) system as the UBP components. The study contributes significantly to the literature by providing new evidence because the previous studies have never targeted the COVID-19 period in assessing the UBP. The main findings are: first, the SUP was still effective enough to reduce household waste even during COVID-19 period though the SUP effectiveness was slightly offset due to the pandemic environments; second, the TTP worked well to restrain household waste under COVID-19 period, when people became cautious about their excessive waste volumes beyond the TTP criteria. The policy implication is a further need to expand municipal adoptions of the UBP system for household waste reduction.

Keywords: COVID-19, Japan, Unit-based pricing (UBP), Simple unit-pricing (SUP), Two-tiered pricing (TTP), Household waste

JEL Classification: Q53, Q58, O53

1. Introduction

COVID-19 had great impacts on people's lives in many aspects. In Japan, since the government announced the declaration of a state of emergency in 2020, the people had been forced to refrain themselves from going out and stay at home through remote works and studies for a long time, and this behavior had also influenced on the volume of household waste. Looking at the long-term trend in nationwide volume of household waste (per capita per day) in Figure 1[1], the volume shows a declining trend for the decade from 527g in 2013 to 496 g in 2022. Its backgrounds are considered to be the enhancement in people's environmental consciousness and the governmental policies to reduce the waste. It should be noted that the waste volume increased remarkably in 2020, the starting year of COVID-19. Several previous studies such as Asai (2023) and Ishimura and Yamaguchi (2022) interpret the increase in the waste in 2020 as the COVID-19 effect through their own questionnaire surveys. However, the waste volume has declined rapidly since 2021 coming back to its previous declining trend.

Regarding the government policies to reduce household waste generation, the system of imposing charges for waste disposal, namely, unit-based pricing of solid waste (hereafter UBP) is one of the key measures at a municipal level. The adoption of the system has started to be disseminated among municipality since the 1990s (Yamakawa and Yano 2008), and the adoption ratio in terms of municipal number reached approximately 60 percent in 2024[2]. The central government also has encouraged the system adoption in municipality through its basic police revised in 2016[3], by stating that municipality should promote the UBP system for waste disposal, which provides economic incentives to facilitate waste reduction, recycling, and the enhancement of environmental consciousness (Ministry of Environment 2020). The UBP system can be roughly divided into two kinds: simple unit-pricing (SUP) and two-tiered pricing (TTP) programs (Yamatani 2020). The former is the system in which the charge is imposed in proportion to the waste volume, while the latter is the one in which the charge is imposed or increased beyond a certain limit of the volume. The adoption ratio of SUP out of total UBP accounts for approximately 90 percent in terms of municipal number, whereas that of TTP accounts only for less than 10 percent (Ministry of Environment 2020).

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[1] The data are retrieved from the survey on the "State of Discharge and Treatment of Municipal Solid Waste" by Ministry of Environment in Japan. See the website: https://www.env.go.jp/recycle/waste_tech/ippan/index.html

[2] See the website: https://www.yamayashusaku.com/zenkokutoshi_yuryoka_2406.pdf.

[3] The basic policy is based on the "Act on Waste Management and Public Cleaning". See the website: https://www.japaneselawtranslation.go.jp/ja/laws/view/4529.

The UBP system for waste disposal has been evaluated by academic research in the world including Japan as stated in Section 2. The majority of the studies appreciated the effectiveness of the system in reducing waste volume, though some studies were doubtful on its effects. To the best of our knowledge, no empirical studies have ever accessed the effectiveness of the UBP system during COVID-19 period, while COVID-19 affected largely the volume of household waste as shown in Figure 1. The motivation of this study is to fill the research gap in the area of evaluations of the UBP system.

The purpose of this study is to identify the effectiveness of the UBP system for household waste disposal including SUP and TTP with a focus on COVID-19 period after 2020 through a panel data analysis targeting 770 cities for 2013-2022.

The remainder of this study is structured as follows. Section 2 reviews the literature related to the evaluation of the UBP system and clarifies this study's contributions. Section 3 conducts the empirical analyses for evaluating the UBP focusing on COVID-19 period including the descriptions of key variables, data, estimation method and results with discussions. Section 4 summarizes and concludes the study.

2. Literature Review and Contributions

This section reviews the literature related to the evaluation of the UBP system in foreign countries and Japan, and clarifies this study's contributions.

In selected advanced economies, a number of empirical studies provided the evidence of verifying the effectiveness of the UBP system: Carratini et al. (2018) in Switzerland, Allers (2010) in the Netherlands, Huang et al. (2011) and Fullerton and Kinnaman (1996) in the United States.

In Japan, the empirical studies for evaluating the UBP have evolved their methodologies towards sophisticated ways from case studies through cross-section data analyses to panel data analyses (The reviewed literature are listed in Table 1). The case studies including questionnaire surveys are, for instance, Yamatani (2011) focusing on Tama city, Sakai et al. (2008) targeting four cities (Singu, Takayama, Oume, and Nagoya), and Amano et al. (1999) covering 19 cities. They all support the effectiveness of the UBP on solid waste reduction.

The cross-section data analyses enable the research results to be more objective and generalized than the case studies. Ichinose et al. (2015) proved waste reduction effects of the UBP by applying an environmental Kuznets curve. Nakamura and Kawase (2011) quantified waste reduction effects of the UBP: one-yen increase in designated one-liter bag produces waste reduction by 1.6 percent. Usui (2008), Suwa and Usui (2007), Usui

(2003) verified interactive effects between waste reduction and recycling promotion. Yamakawa and Ueta (2002) demonstrated the sustainable (ten-year) effects of the UBP on waste reduction using cross-sections with three-point years. In contrast, Fukuda et al. (2021) examined the UBP impact using a geographically weighted regression and argued that the current pricing in most of municipalities did not have significant effects on waste reduction. Sasao (2000) showed that the waste reduction effect of the UBP are more remarkable in rural areas than in rural areas.

The panel data analyses make possible more precise and dynamic estimations than the cross-section data analyses. Nomura and Hibiki (2020) examined the UBP effects considering a spatial correlation between municipalities and found significant effects on waste generation. Tsuzuki et al. (2018) constructed municipal-level panel data considering the municipal mergers known as "the big merger of Heisei" and verified the waste reduction effects of the SUP and TTP over a long period of time. Usui and Takeuchi (2014) and Usui (2011) investigated the rebound effect of the UBP in which the waste reduction effects fade out after the UBP adoption and found that the long-term waste reduction effects of the UBP dominated its rebound effect.

In sum, the majority of previous studies appreciated the effects of the UBP on waste reduction, but some studies were negative on the effects. Thus, the UBS effectiveness did not fully reach a consensus in the literature.

Based on the reviewed literature, this study, evaluating the UBP targeting COVID-19 period, provides the following contributions. First, the study enriches the evidence of the UBS effectiveness while the previous studies showed its mixed results. Second, the study create new evidence because the previous studies have never targeted the COVID-19 period in assessing the UBP. Third, the study provides significant evidence because the COVID-19 might change people's consciousness and behavior on household waste disposal as suggested by the change of the trend in nationwide volume of waste after 2020 in Figure 1. The critical question arises whether people's reactions against the UBP would have been strengthen or weakened.

3. Empirical Analyses

This section conducts the empirical analyses for evaluating the UBP focusing on COVID-19 period including the descriptions of variables, data, estimation method and results with discussions. The section starts with the description of variables and data.

3.1 Variables and Data Collection

This subsection describes the variables and data collection for the subsequent econometric estimation. The variables and their data used for the subsequent estimations are listed in Table 2, and their descriptive statistics are presented in Table 3. The estimation contains one dependent variable of household waste, four explanatory variables for controlling time-varying city-specific effects, and two kinds of explanatory dummies: the ones for examining the effect of the UBP municipal adoption and the others of COVID-19-period dummies.

The dependent variable, household waste (*was*), is expressed as the one per person and day in terms of gram. Its data are retrieved from the survey by Ministry of Environment as described in Note 1.

Regarding the explanatory variables, the first category is the variables for controlling time-varying city-specific effects. The first three variables are the ones representing municipal social properties: average number of people per household (*hos*), taxable income per capita in terms of yen (*inc*), and population density based on a habitable area in terms of persons per the square of kilometers (*pod*). These variables are selected from those commonly used in previous studies in the literature shown in Table 1. All of their data are retrieved from the Statistical Observations of Municipalities by Ministry of Internal Affairs and Communications[4]. The data of *inc* and *pod* are transformed into logarithms form (*ln inc* and *ln pod*) to avoid scaling problems in the estimation. The effects of these variables on household waste were ambiguous in the literature. While the effect of number of people per household (*hos*) on waste was negative due to the increase in common waste among members in most of previous studies, some studies such as Asai (2023) showed its positive effect owing to additional increase in household waste originating from the family supports for children and elder members. The income (*inc*) effect on waste was positive owing to the increase in consumption in the majority of studies (e.g., Sasao 2000, Usui 2003), but the other such as Nomura and Hibiki (2020) presented its negative effect assuming dining-out effects stemming from high-income earnings. As for the effect of population density (*pod*) on waste, some studies such as Usui (2003) indicated a positive effect due to the limited spaces for waste storage, whereas the others such as Nomura and Hibiki (2020) and Tsuzuki et al. (2018) presented a negative effect by the incentive of waste reduction. Another control variable is the one representing municipal waste treatment, namely, number of garbage collection separation (*sep*). Its data are from the survey by Ministry of Environment in Note 1. Its negative

[4] See the website: https://www.stat.go.jp/data/s-sugata/index.html.

effect on waste was proven in previous studies as is expected.

The second category is the explanatory variables of dummies. The first two dummies are the ones of the UBP municipal adoption: the adoptions of the SUP (*d_sup*) and TTP (*d_ttp*), taking a value of one during their adopted periods and zero otherwise[5]. The information for their adoptions are taken from Yamatani (2024). The negative effects of both systems on waste are expected as the majority of previous studies appreciated the effects of the UBP on waste reduction as described in Section 2. Comparing the effects of the SUP and TTP, the SUP effect is supposed to be more robust than the TTP effect because the SUP provides the incentive of waste reduction by every unit of waste though the TTP confines its incentive only to the volume beyond the criteria. The other three dummies are COVID-19-period ones: the dummy after 2020 (*d_post20*) taking a value of one after 2020 and zero otherwise, the one after 2021 (*d_post21*), and the one for 2022 (*d_post22*). Following the observation in Figure 1, the effect of *d_post20* on waste seems to be positive, while the other dummies (*d_post21*, and *d_post22*) appears to be negative. The greatest concern of this study is to investigate whether the waste reduction effect of the UBP was changed during COVID-19 period, and if it was, in which directions the change was happening: its waste reduction effect is strengthen or weakened. Thus, the cross-terms are created and added to the estimation in line with this interest: *d_sup**d_post20*, *d_sup**d_post21*, and *d_sup**d_post22* for the SUP additional effect, and *d_ttp**d_post20*, *d_ttp**d_post21*, and *d_ttp**d_post22* for the TTP additional effect.

3.2 Panel Data Setting

Based on the above setting of the variables, this study constructs panel data using annual data for 2013–2022[6] in 770 cities. This study excludes the following cities and periods from the sample due to the complexity in examining the UBP effect: the cities that had adopted the TTP and changed it into the SUP, the 23 wards in Tokyo Metropolitan, and the periods before the status of current "city" in case of any changes of status (e.g., mergers, upgrades from towns or villages). Given the exclusion, the panel data finally comprises 7,689 samples. Among 770 sample cities, the SUP and TTP have been adopted by 439 and 21 cities in 2022, respectively.

For the subsequent estimation, the study investigates the stationary property of the constructed panel data by employing panel unit root tests: the Levin, Lin, and Chu test as

[5] In case the timing of the adoption is a midway of year, a value of one is applied from next year.

[6] The sample period is set by the data availability of household waste from the survey by Ministry of Environment as in Note 1. The annual year demotes the fiscal year in Japan from April to March.

a common unit root test (Levin et al. 2002) and the Fisher Augmented–Dickey–Fuller (ADF), Fisher Phillips–Perron (PP) tests (Choi 2001, Maddala and Wu 1999) as individual unit root tests. The common unit root test assumes the existence of a common unit root process across cross-sections, whereas the individual unit root test allows individual unit root processes that differ across cross-sections. These tests are conducted based on the null hypothesis that a series of panel data in levels has a unit root by including the "trend and intercept" in the test equations. Table 4 shows that all the tests except one variable (*ln pod*) in Fisher–ADF test rejects the null hypothesis of a unit root at the conventional significance level for the variables. Therefore, this study assumes there is no serious problem with the existence of unit roots in the panel data, and uses the panel data in levels for the estimation.

3.3 Model Specification and Estimation Method

The equation for the econometric estimation, following the panel data analyses in the literature, is specified as follows:

$$\begin{aligned} was_{it} = {} & \alpha_0 + \alpha_1\, hos_{it} + \alpha_2\, ln\ inc_{it} + \alpha_3\, ln\ pod_{it} + \alpha_4\, sep_{it} + \alpha_5\, d\_sup_{it} + \alpha_6\, d\_ttp_{it} \\ & + \alpha_7\, d\_post20 + \alpha_8\, d\_post21 + \alpha_9\, d\_post22 \\ & + \alpha_{10}\, d\_sup_{it}\, d\_post20 + \alpha_{11}\, d\_sup_{it}\, d\_post21 + \alpha_{12}\, d\_sup_{it}\, d\_post22 \\ & + \alpha_{13}\, d\_ttp_{it}\, d\_post20 + \alpha_{14}\, d\_ttp_{it}\, d\_post21 + \alpha_{15}\, d\_ttp_{it}\, d\_post22 + f_i + \varepsilon_{it} \end{aligned} \quad (1)$$

Here each of the variable names was denoted in Section 3.1 and Table 2. Subscripts i and t represent the sample city and year, respectively. f_i shows a time-invariant city-specific fixed effect. $\alpha_{0...15}$ stands for the estimated coefficients and ε denotes the residual error term. Equation (1) is the full version of the estimation including all the variables. The subsequent estimations start with the equation without any dummy variables, followed by the equations with the dummies of *d_post20*, *d_post20 and d_post21*, and *d_post20*, *d_post21*, and *d_post22*, for the purpose of demonstrating a series of annual accumulation of additional COVID-19 effects including the UBP effects on waste reduction in their cross-terms (the additional effects are shown in a_i-iv of Table 5 and b_i-iv of Table 6 in Section 3.4).

The panel-data analysis provides an option for choosing a fixed- or random-effect model. Equation (1) applies a fixed-effect model, represented by f_i, for the municipal panel data estimation for the following reasons. First, from a statistical perspective, the Hausman specification test is generally utilized to choose between the fixed- and random-effect models (Hausman 1978). The test was conducted in the primary equation (1) without period dummies and resulted in a rejection of null hypothesis of the random effect model at 99 percent significant level with the Chi-Square statistic being 226.7. Thus, the test justifies the adoption of the fixed effect model. Second, adopting the fixed-effects model helps alleviate the endogeneity problem by absorbing unobserved time-invariant heterogeneity among the sample cities. Assume that geographical factors such as climate and reginal culture differ among sample cities and are correlated with household waste (not distributed randomly among sample cities). As a specification ignoring these effects leads to inefficient estimation, they should be controlled for by incorporating city-specific fixed effects into the specification.

Multicollinearity among the explanatory variables is one of problems that lead to estimation bias, and the variance inflation factors (VIF) is a useful tool of measuring the level of collinearity between regressors. The VIF test is conducted in the primary equation (1) without period dummies and its values are found to be far below the criteria of collinearity, namely, 10 points–3.453 in *hos*, 2.848 in *ln inc*, 1.604 in *ln pod*, 1.025 in *sep*, 1.027 in *d_sup*, and 1.007 in *d_ttp*. Thus, the inclusion of all the explanatory variables is justified in the estimation.

Regarding the estimation technique, this study applies the ordinary least squares (OLS) and the generalized least squares (GLS) estimators. The reason for applying the GLS estimator is that the sample data would be plagued by heteroskedasticity among sample cities, where the OLS estimator leads to bias in estimates. For examining the existence of heteroskedasticity in sample cities, the panel cross-section heteroskedasticity likelihood ratio test was conducted in the primary equation (1) without period dummies and resulted in a rejection of null hypothesis that residuals are homoscedastic at 99 percent significant level. Thus, this study adds the GLS estimation to ensure the robustness of the estimation results.

3.4 Results with Discussion

Tables 5 and 6 report the results for the OLS and GLS estimations on the household waste effects, respectively. The estimation results of a_i-iv of Table 5 and b_i-iv of Table 6 represent a series of annual accumulation of additional COVID-19 effects. The results common in both estimations are prioritized as robust ones in their findings. The main results are summarized as follows.

Regarding the effects of the variables for controlling time-varying city-specific effects, the first variable, the number of people per household (*hos*), has significantly positive coefficients through both estimations. This result is in line with that of Asai (2023), pointing out the additional increase in household waste originating from the family supports for children and elder members. The income (*ln inc*) effects are significantly negative throughout the estimations, which are aligned with Nomura and Hibiki (2020) speculating dining-out effects of high incomers. The effects of population density (*in pod*) are significantly negative throughout the estimations, which are in line with Nomura and Hibiki (2020) and Tsuzuki et al. (2018) assuming the incentive of waste reduction under limited spaces. The number of garbage collection separation (*sep*) has significantly negative effects as verified in many of previous studies.

The COVID-19-period dummies present expected effects in both estimations: the dummy after 2020 (*d_post20*) has significantly positive effects (except the a_ii estimation) whereas the dummies after 2021 (*d_post21*) and after 2022 (*d_post22*) have negative ones. The negative magnitudes of the sum of *d_post21* and *d_post22* exceed the positive one of *d_post20*. These results are consistent with the trend in household waste observed in Figure 1. The results can be interpreted such that in 2020 as the initial year of COVID-19 people were unexpectedly forced to stay at home for a long time and thus could not prevent household waste from increasing; however, in 2021 and 2022 COVID-19 effects became mitigated and people also could adjust themselves to COVID-19 environment, thereby being able to manage well waste disposal.

The greatest concern of this study is the waste reduction effects of the municipal UBP adoption, in particular, those in COVID-19 period. The SUP effects (*d_sup*) are significantly negative and their magnitude is 50-60 gram per person and day throughout the estimations. However, the TTP effects (*d_ttp*) are not necessarily significant–insignificant in the OLS estimations, a_ii-iv, and their magnitude is 30-40 gram per person and day in the GLS estimation, b_i-iv. These results are consistent with the majority of previous studies in Section 2 and also the original expectation that the SUP effect is more robust than the TTP one due to the difference in their waste reduction incentives.

What is more important is how the UBP' waste reduction effects changed during COVID-19 period. The additional UBP effects during COVID-19 are represented by the cross-terms with COVID-19-period dummies. Regarding the SUP additional effects, they are significantly positive (except for the OLS estimation, a_iv), but their magnitude is far smaller than the original SUP effects. The magnitude of the cumulative SUP effects as the sum of original and additional effects is 40-50 gram per person and day throughout the estimations. It suggests that the SUP was still effective enough to reduce household waste even during COVID-19 period though the SUP effectiveness was slightly offset due to the pandemic environments affecting largely people's behaviors. As for the TTP additional effects, it should be noted that the results common in the OLS and GLS estimations are significantly negative effects in the cross-term with *d_post20*. It suggests that people became cautious about whether their waste volumes exceed the TTP criteria in the pandemic environments where they stayed at home for a long time and produced more waste than usual.

4. Conclusion

This study aimed to identify the effectiveness of the UBP system for household waste disposal including SUP and TTP with a focus on COVID-19 period after 2020 through a panel data analysis targeting 770 cities for 2013-2022. The study is significant enough to provide new evidence because the previous studies have never targeted the COVID-19 period in assessing the UBP. The main findings can be highlighted as follows. First, the SUP was still effective enough to reduce household waste even during COVID-19 period though the SUP effectiveness was slightly offset due to the pandemic environments. Second, the TTP worked well to restrain household waste under COVID-19 period, when people became cautious about their excessive waste volumes beyond the TTP criteria.

The policy implication of this study is a further need to expand municipal adoptions of the UBP system. Its effectiveness on household waste reduction was verified even during the pandemic situation in this study. However, its the adoption ratio in terms of municipal number currently stayed at approximately 60 percent. Thus, the UBP dissemination would contribute to further waste reduction through the enhancement of people's incentives and environmental consciousness.

This study has the following limitations and frontiers for further research. First, this study focuses only on the waste reduction effect of the UBP system. However, the UBP is considered to promote not only waste reduction but also recycling. For examining the UBP recycling effects, detailed analyses should be conducted based on the data decomposing household wasted into burnable waste, non-burnable one, and recyclable waste for seeing explicitly the shifts among the waste. Second, this study targets only household waste. However, the UBP has been applied not only to household waste but also business-related waste. Thus, the comprehensive reviews of the UBP system would require an additional investigation of the effects of the UBP on business-related waste.

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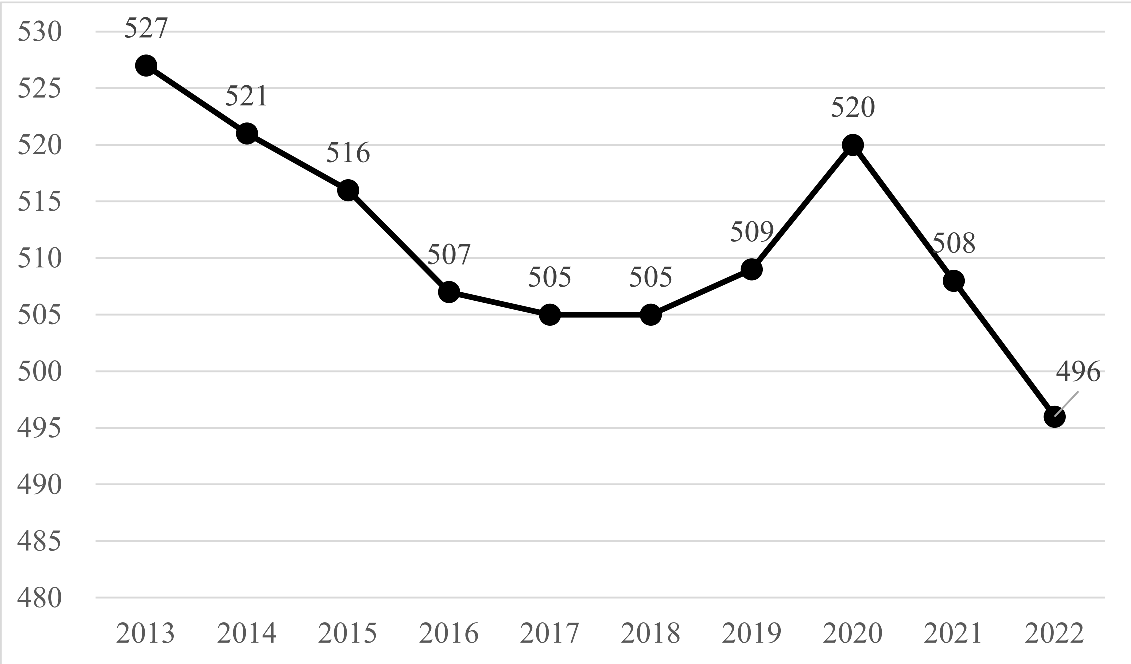
Figure 1 Trend in Household Waste (per capita, per day, g)



Source: Authors' description based on the databases of Ministry of Environment

Table 1 List of Literature

Types of Analyses	Literature	Effects of Charge
Case Studies	Yamatani 2011	+
	Sakai et al. 2008	+
	Amano et al. 1999	+
Cross Section Data	Fukuda et al. 2021	-
	Ichinose, et al. 2015	+
	Nakamura & Kawase 2011	+
	Usui 2008	+
	Suwa & Usui 2007	+
	Usui 2003	+
	Yamakawa & Ueta 2002	+
	Sasao 2000	-
Panel Data	Nomura & Hibiki 2020	+
	Tsuzuki et al. 2018	+
	Usui & Takeuchi 2014	+
	Usui 2011	+

Sources: Authors' description

Table 2 List of Variables and Data Sources

Variables	Description	Data Sources
Dependent Variable		
was	Household waste (per person, per day), g	W
Explanatory Variables		
hos	Average number of people per household	M
inc	Taxable income per capita, yen	M
pod	Population density based on a habitable area, per km^2	M
sep	Number of garbage collection separation	W
d_sup	Dummy (=1) for municipalities adoption of single unit pricing	Y
d_ttp	Dummy (=1) for municipalities adoption of two-tiered pricing	Y
d_post20	Dummy (=1) for COVID-19 period after 2020	
d_post21	Dummy (=1) for COVID-19 period after 2021	
d_post22	Dummy (=1) for COVID-19 period in 2022	

Note: W: State of Discharge and Treatment of Municipal Solid Waste, by Ministry of Environment
M: Statistical Observations of Municipalities, Ministry of Internal Affairs and Communications
Y: Yamatani (2024)
Sources: Authors' description

Table 3 Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max
was	7,689	662	91	312	1,283
hos	7,689	2.346	0.255	1.656	3.243
ln inc	7,689	14.897	0.140	14.552	15.767
ln pod	7,689	6.962	1.076	4.127	9.604
sep	7,689	14.258	4.979	3.000	36.000

Sources: Authors' description

Table 4 Panel Unit Root Tests

	common unit root	individual unit root	
	Levin, Lin, and Chu Test	Fisher-ADF Chi-square	Fisher-PP Chi-square
was	-52.010***	2,123.96***	2,295.75***
hos	-65.969***	3,144.14***	5,718.90***
ln inc	-22.482***	1,669.27**	1,848.61***
ln pod	-51.974***	1,427.35	2,126.09***
sep	-541.839***	1,032.89***	1,149.37***

Note: ***, and **denote statistical significance at the 99, and 95 percent level, respectively.
Sources: Authors' estimation

Table 5 OLS Estimation

Estimation	a_i	a_ii	a_iii	a_iv
hos	31.727*** (4.500)	48.399*** (6.151)	50.305*** (6.413)	51.184*** (6.535)
ln inc	-175,081*** (-10.183)	-205.744*** (-11.756)	-162.285*** (-8.698)	-143.830*** (-7.594)
in pod	-159.293*** (-13.349)	-149.475*** (-12.519)	-150.358*** (-12.645)	-151.904*** (-12.794)
sep	-1.420*** (-5.174)	-1.427*** (-5.220)	-1.455*** (-5.343)	-1.256*** (-5.359)
d_post20		1.304 (0.911)	9.499*** (5.085)	9.109*** (4.882)
d_post21			-15.038*** (-7.337)	-11.415*** (-4.924)
d_post22				-8.448*** (-3.637)
d_sup	-56.202*** (-15.704)	-60.255*** (-16.824)	-60.365*** (-16.926)	-60.363*** (-16.957)
*d_sup*d_post20*		10.863*** (7.233)	4.328* (1.891)	4.275* (1.871)
*d_sup*d_post21*			9.537*** (3.649)	9.059*** (3.009)
*d_sup*d_post22*				0.810 (0.269)
cumulated d_sup	-56.202	-49.392	-46.500	-47.029
d_ttp	-40.298** (-2.136)	-28.901 (-1.534)	-30.130 (-1.606)	-30.589 (-1.634)
*d_ttp*d_post20*		-15.007*** (-3.304)	-15.746** (-2.276)	-15.805** (-2.275)
*d_ttp*d_post21*			1.537 (0.193)	2.906 (0.317)
*d_ttp*d_post22*				-2.654 (-0.290)
Adjusted R-squared	0.897	0.899	0.899	0.900
Fix Effect (cities)	Yes	Yes	Yes	Yes
Number of cities	770	770	770	770
Obsevations	7,689	7,689	7,689	7,689

Note: Note: ***, **, and * denote statistical significance at the 99, 95, and 90 percent level, respectively. T-statistics are shown in parentheses.
Sources: Authors' estimation

Table 6 GLS Estimation

Estimation	b_i	b_ii	b_iii	b_iv
hos	40.279***	68.676***	73.357***	76.190***
	(10.005)	(15.912)	(17.195)	(18.080)
ln inc	-197.551***	-235.700***	-183.603***	-157.348***
	(-19.960)	(-23.989)	(-17.689)	(-15.369)
in pod	-181.037***	-170.426***	-169.537***	-171.295***
	(-25.969)	(-25.243)	(-25.614)	(-26.269)
sep	-1.533***	-1.491***	-1.578***	-1.599***
	(-9.453)	(-10.123)	(-10.443)	(-10.497)
d_post20		5.063***	13.387***	13.100***
		(6.681)	(13.865)	(13.863)
d_post21			-15.137***	-11.025***
			(-14.271)	(-9.420)
d_post22				-10.004***
				(-8.549)
d_sup	-51.745***	-56.110***	-56.094***	-56.071***
	(-21.847)	(-23.984)	(-24.237)	(-24.519)
*d_sup*d_post20*		10.402***	2.851**	2.882**
		(13.169)	(2.422)	(2.484)
*d_sup*d_post21*			11.197***	8.475***
			(8.343)	(5.554)
*d_sup*d_post22*				4.847***
				(3.178)
cumulated d_sup	-51.745	-45.708	-42.046	-39.867
d_ttp	-38.272***	-28.355**	-29.922***	-30.393***
	(-4.784)	(-2.542)	(-2.833)	(-2.909)
*d_ttp*d_post20*		-10.469***	-13.209***	-12.496***
		(-3.907)	(-3.234)	(-3.044)
*d_ttp*d_post21*			4.664	2.451
			(1.009)	(0.456)
*d_ttp*d_post22*				1.932
				(0.359)
Adjusted R-squared	0.965	0.965	0.966	0.966
Fix Effect (cities)	Yes	Yes	Yes	Yes
Number of cities	770	770	770	770
Obsevations	7,689	7,689	7,689	7,689

Note: Note: ***, **, and * denote statistical significance at the 99, 95, and 90 percent level, respectively. T-statistics are shown in parentheses.

Sources: Authors' estimation