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Evaluating Unit-Based Pricing of Residential Solid Waste: A Panel Data Analysis

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Abstract Municipalities introduced unit-based pricing (UBP) with the aim of achieving a decrease in household waste generation and for the replacement of unsorted waste with recycling. Although many studies have shown that UBP has a short-run effect on recycling, few works have tackled the long-run effect on waste generation and recycling. By using panel data for 665 Japanese cities over 8 years, we examine the long-run effect of UBP on waste generation and recycling. The estimation results in waste generation suggest that there is a rebound effect, though a small one. We confirm that the effect of UBP on recycling sustains for the long run. We also find that the short- and long-run responses to an economic incentive for recycling activities differ with income groups. Recycling among the high-income group has not been promoted by implementation of UBP, but people in that group are willing to participate in recycling without an economic incentive. In contrast, recycling activity within the low-income group is strongly motivated by UBP for many years.

Keywords Unit-based pricing · Waste reduction · Recycling · Panel data analysis · Long-run effect

The unit-based pricing (UBP) of residential solid waste collection has been implemented in many parts of the world, including municipalities[1] in the United States, the EU, and South Korea (OECD 2006). This also applies to Japan, a country with limited space for landfill waste, where its Ministry of the Environment has encouraged and supported municipalities to

[1] In Japan a municipality is defined as a village, town, or city.

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introduce UBP.[2] Expecting to achieve waste reduction and the substitution effect of recycling, the proportion of municipalities introducing UBP increased from 50 to 78 % between 1999 and 2009 (Ministry of Environment, Japan 2001, 2011). However, several years after the introduction of UBP, some municipalities reported an increase in waste generation over what was generated during the first year of the introduction of UBP. This paper focuses on the long-run reduction and substitution effects of UBP.

Government and municipality officials in Japan suspect there is a long-run reduction effect connected with UBP, though they keep encouraging its introduction. The Ministry of Environment added a caveat against UBP, saying "We are concerned about the erosion of the reduction effect after a few years have passed, because people become less and less sensitive to the price burden and do not attempt to reduce their waste. In order to retain the reduction effect, it is efficacious to supply information to citizens to help their understanding" (Ministry of Environment, Japan 2007, p. 41).[3] Yamaya (2007) also points out that municipalities need to take additional steps to promote waste reduction after they introduce UBP.

Many municipalities hesitate to implement UBP because they believe that, even if a bag price is introduced, a rebound will occur within a couple of years. For example, Nagano City stated that, "Since the introduction of UBP, we continuously check the reduction effect and take steps to prevent the rebound effect" (Nagano City 2007, p. 4). Otsu City maintained that "Rubbish generation increased by 1.1 times that of the previous year. In the examples of other cities we see a continuous gradual increase in a waste rebound under UBP" (Otsu City 2011, p. 1). However, these claims do not seem to be based on conventional statistical analysis.

In spite of the anxiety expressed by municipalities, the rebound effect of UBP has not received much attention in previous studies on the economics of household waste management. For example, among the studies reviewed by Kinnaman (2006), most of them used cross-sectional or panel data gathered for less than 3 years and focused on the short-run effect of UBP. Policy evaluation based on these estimates will be misleading in the long run, if there is any possibility of a rebound effect. A few studies have addressed the long-run effect of UBP (Amano et al. 1999; Yamakawa and Ueta 2002; Linderhof et al. 2001; Dijkgraaf and Gradus 2009), but they have shortcomings with regard to geographical coverage of data or econometric techniques, as we will see more precisely in the next section.

Our study adds to the contributions of earlier literature by estimating the long-run price effects in UBP, paying careful attention to the problems of sample representation and endogeneity. We estimate the long-run reduction effect using figures on the municipal solid waste of *all* Japanese cities, obtained through a panel data set. We also test the long-run effects of UBP with respect to waste reduction and recycling. Note that UBP has been adopted not only to encourage households to reduce overall waste and reallocate waste from the unsorted waste pile to the recycling pile, but also to make people continue these activities over the years. Also, the long-run effect of UBP might be different between income groups, since there is a difference in opportunity cost of time and environmental awareness. To sum up, our research goal is to (1) test whether or not there is a rebound effect in waste generation; (2) test for a rebound effect in recyclable waste collection; and (3) test for a rebound effect between different income groups.

[2] Japan's direct landfill rate was only 11 % in 1995, the lowest among OECD countries. Compare this figure with, for example, 57 % in the USA and 83 % in the UK (see OECD 2008, p. 16). In Japan municipal solid waste is mainly dealt with by having households first separate out recyclable materials and then incinerating what is left, thus reducing the volume of waste.

[3] This manual is distributed to all municipalities in Japan. This is our partial summary and translation of the caveat.

The paper is organized as follows. The next section explores previous relevant literature on estimation of the short-run and long-run effects of UBP, and it clarifies their relation with a rebound effect. Sections 2 and 3 describe the econometric model employed and the type of data used, respectively. Next, Sect. 4 presents a detailed report of the estimation results. In Sect. 5 we go on to discuss the long-run effect of UBP in different income groups. The final section contains the concluding remarks.

1 Relevant Literature

Before summarizing the relevant literature, in Subsection 1.1 we first explain the short-run and long-run effects of UBP as well as the rebound effect, and clarify their mutual relationships. Subsection 1.2 reviews literatures in behavioral economics and social psychology as theoretical underpinnings of the study on rebound effect. In Subsections 1.3 and 1.4 we summarize previous studies of short-run and long-run effects, respectively, concluding the latter with a statement of our research goal: to clarify whether a rebound effect occurs or not.

1.1 Explanation of Short-Run, Long-Run, and Rebound Effects

The short-run effect of UBP means the price effect of UBP relative to waste generation over only 1 year, estimated by cross-section or panel data analysis, while the long-run effect, over a longer period of time, is almost always estimated by panel data analysis, and very rarely by cross-section analysis.[4]

A rebound effect that is part of a long-run effect can be defined as an effect of UBP in the long run that can be attributed to the UBP, not some other cause. Figure 1 gives a simple illustration of the rebound effect, with the amount of waste per capita in the vertical axis and time in the horizontal axis. In this figure, we assume that there is a positive time trend in waste generation. When UBP is introduced at time t_1, the amount of waste decreases from r_0 to r_1. The vertical distance between r_0 and r_1 can be regarded as the short-run price effect. A few years after the introduction of UBP, waste generation per capita might seem to increase and approach the level before the introduction. This may not necessarily be a rebound effect, since there might be a positive time trend in waste generation. As long as the predicted waste generation (the dashed line) and realized waste generation (the solid line) run parallel, there is no rebound because the increasing tendency cannot be attributed to the effect of UBP. But if the slope of the latter is greater than the former, there is a rebound effect. To detect the effect, it is necessary to consider the impact of UBP on waste reduction under the ceteris paribus condition, for example, by controlling the varying waste composition with the age structure of residents or with an increase in consumption during the period. On the other hand, if waste generation decreases below the dashed line in Fig. 1, we define this as an inverse rebound effect. Different rebound effects in the long run arise because of a mixed effect of negative and positive changes in citizens' behavior. An example of a negative effect is awareness erosion: the effectiveness of UBP erodes over time if households get used to paying for waste and revert to their old behavior (Dijkgraaf and Gradus 2009). An example of a positive effect is the learning effect, whereby citizens gradually learn how to reduce general waste by sorting out recyclable objects and choosing goods with less packaging.

[4] To our knowledge there are no studies of time-series analysis.

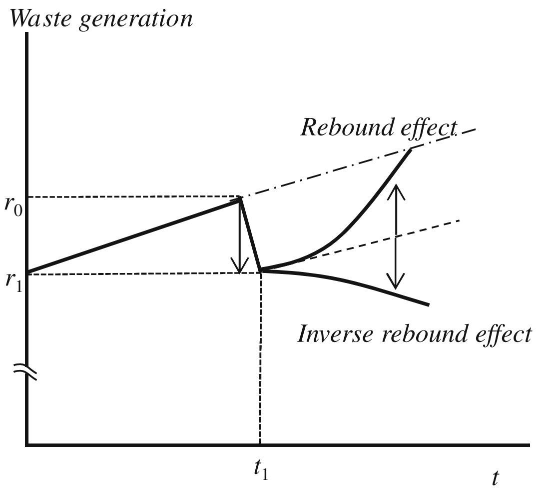

Fig. 1 Definition of long-run effect

1.2 Theoretical Backgrounds

Conventional economic theory suggests that the demand for waste collection should become more price-elastic with time, since alternative ways to reduce waste become available in the long run. Therefore, an assumption beyond the standard economics is necessary to explain the existence of the rebound effect. Concepts and theories suggested in behavioral economics and social psychology are useful to understand why demand for waste collection become less responsive to UBP as time passes.

The model of self-control has been developed to explain demand for addictive goods such as alcohol and cigarettes. For example, Gruber and Koszegi (2001, 2004) extend the model of rational addiction to incorporate the role of mistakes. They suggest that present bias and the lack of self-control are key features to explain a large number of failed attempts to quit smoking. Assuming willpower to be a depletable resource, Ozdenoren et al. (2012) show that individuals may increase consumption over time because exercising self-control later requires more willpower than exercising the same level of self-control earlier. While waste collection is not usually characterized as an addictive good, the concept of self-control is an aid to understanding why attempts at changing behavior easily fail and people become less responsible to a price signal. In addition, while UBP provides households with an incentive to reduce waste and to recycle more, households can assess the cost of doing these activities at home only through doing them. When households engage for a while in source reduction of waste and in separating waste for recycling, they might come to realize that the cost of such activities is higher than their perceived benefit. This leads to a gradual cessation of these pro-environmental activities, a situation that Dijkgraaf and Gradus (2009) termed "awareness erosion."

The theory of "motivation crowding out" that was developed mainly in the field of social psychology is another possible explanation of the rebound effect. It generally refers to the situation in which rewarding an activity with an economic incentive causes people to reduce its voluntary supply (Deci 1971). Benabou and Tirole (2003) assume initially uncertain preferences and show that rewards can lead to changes in the expected utility attached to an action. When a heterogenous delay in the changes in the expected utility occurs among the population, the effect of a relative price change is gradually dominated by the crowding out effect, which in turn leads to a rebound effect.

In contrast to the notion of rebound effect, demand response to the price incentive may also be stronger in the long run. This can be defined as an inverse rebound effect. A model of social norm developed by Rege (2004) might explain this phenomenon. In her model, people obtain utility from social approval when others are appreciative of their behavior. The amount of social approval depends on the difference between one's contribution and the average contribution. When people learn to play the utility maximization strategy by trial and error, there can be two stable states, one in which everybody is a contributor, and one in which nobody is a contributor. This means that, depending on the initial starting point, either a rebound effect or an inverse rebound effect can arise.

1.3 Short-Run Studies

There is a considerable amount of empirical literature on waste reduction through UBP in the short run. Notably, there has been an increase in studies on the practice of separating recyclable objects from waste, which has provided an incentive to UBP (e.g., Hong et al. 1993; Saltzman et al. 1993; Reschovsky and Stone 1994; Callan and Thomas 1997; Nestor and Podolsky 1998; Hong and Adams 1999; Bartelings and Sterner 1999; Kinnaman and Fullerton 2000; Jenkins et al. 2003; Callan and Thomas 2006; Allers and Hoeben 2010; Huang et al. 2011; for a recent review, see Ferrara 2008).

However, analyses that treat policy changes as natural experiments may yield biased estimates of the impact of the policy (Besley and Case 2000). The estimated marginal effect of UBP might be the result of an unobserved variable that is correlated to the price level of UBP. For example, the variable might be the environmental awareness of the community. The omitted variable might also increase the probability of a municipality implementing policies such as a curbside recycling program, and this results in the marginal effect of UBP being overestimated. In this way, an exogeneity assumption of a UBP variable results in a biased estimator.

There are two types of solution, one of which is to use an instrumental variable method to control unobserved variables. Kinnaman and Fullerton (2000), who estimated the demand equations for solid waste and recycling considering the endogeneity of a unit-pricing and curbside-recycling policy, used the two-stage least square (2SLS) method to obtain an unbiased estimator. They estimated the price elasticity of garbage and recyclables, including the correction of endogenous local policy variables. They found that the reduction effect of waste generation is statistically significant, but the substitution effect of recyclable waste is not statistically significant. Callan and Thomas (2006), Usui (2008) and Allers and Hoeben (2010) extended the approach of Kinnaman and Fullerton. Detailed estimation results of each study are shown in Table 1.

Another type of treatment is to use the panel data method. Houtven and Morris (1999), Dijkgraaf and Gradus (2004, 2009), and Allers and Hoeben (2010) applied a fixed-effect model that is represented at community-level dummies. For example, Dijkgraaf and Gradus (2004) provide an empirical analysis of the effects of unit/weight-based pricing of household waste using panel data for The Netherlands. Panel data analysis can easily address the inconsistency of the self-selection bias by controlling for the unobserved intrinsic effect using the fixed-effect model and the random-effect model. They separate out the effect of environmental activism, which stems from differences in citizens' concern about the waste problem.

Table 1 Literature survey: short-run effect of unit-based pricing

Study	Country	System	Own-price elasticity	Cross-price elasticity	Number of years
Aggregate municipal data					
Allers and Hoeben (2010)	Netherlands	Weight (unsorted waste)	−0.65	–	10
Allers and Hoeben (2010)	Netherlands	Bag (unsorted waste)	−0.39	–	10
Callan and Thomas (1997)	USA	Mixed	–	0.07	1
Callan and Thomas (2006)	USA	n.a.	−0.58	0.05	1(?)
Dijkgraaf and Gradus (2004)	Netherlands	Bag (unsorted waste)	−0.62	–	3
Dijkgraaf and Gradus (2004)	Netherlands	Bag	–	0.12	3
Huang et al. (2011)	NW, USA	Bag (total waste)	−0.62	–	1
Jenkins (1993)	USA	Volume	−0.12	–	Various[a]
Kinnaman and Fullerton (2000)	USA	Bag	<0	n.s.	1
Podolsky and Spiegel (1998)	USA	Volume (total waste)	−0.39	–	1
Strathman et al. (1995)	USA	Volume	−0.45	–	?
Suwa and Usui (2007)	Japan	Bag	<0	>0[b]	1
Usui (2008)	Japan	Bag (glass botteles)	–	0.07	1
Usui (2008)	Japan	Bag (PET bottlles)	–	0.12	1
Usui (2008)	Japan	Bag (cans)	–	0.15	1
Usui (2008)	Japan	Bag (paper containers)	–	n.s.	1
Houtven and Morris (1999)	USA	Bag (total waste)	−0.15	–	39 (months)
Wertz (1976)	USA	Volume	−0.15	–	1
Yamakawa and Ueta (2002)	Japan	Bag	<0	–	1
Household surveys					
Fullerton and Kinnaman (1996)	USA	Bag	−0.23	–	2
Fullerton and Kinnaman (1996)	USA	Weight	−0.06	0.07	2
Hong (1999)	Korea	Bag	−0.15	0.46	1
Hong et al. (1993)	USA	Volume	n.s.	>0	?
Jenkins et al. (2003)	USA	Volume (by material)	–	n.s.	1
Linderhof et al. (2001)	Netherlands	Weight (compostable)	−1.39	–	42 (months)
Linderhof et al. (2001)	Netherlands	Weight (unsorted)	−0.34	–	42 (months)
Nestor and Podolsky (1998)	USA	Volume	(?)	–	(?)
Reschovsky and Stone (1994)	USA	Bag (recyclable)	–	n.s.	1(?)
Reschovsky and Stone (1994)	USA	Bag (compostable)	–	>0	1(?)

This table is based on Jenkins et al. (2003) and Dijkgraaf and Gradus (2004), and is updated by the authors; *n.a.* not available, *n.s.* not significant

[a] This paper used various numbers of years for each municipality

1.4 Long-Run Studies

There have been fewer studies of the long-run effect of UBP. In Japan, Amano et al. (1999) and Yamakawa and Ueta (2002) examined the long-run reduction effect of UBP. The former analyzed four municipalities that introduced UBP and compared waste generation per capita for several years before and after the introduction of UBP. They concluded that two municipalities increased waste reduction after the year in which UBP was adopted, but they did not clarify why waste generation increased in their municipalities. Since they defined the rebound as the difference between waste generation per capita before and after UBP, that rebound effect may be partially due to a factor of demographic change, such as greater income, or changes in the waste items collected.

To analyze the long-run effect of UBP properly, demographic change needs to be controlled. Yamakawa and Ueta (2002) also tried to clarify the long-run reduction effect of UBP by using cross-sectional data at the municipality level. Their estimation strategy was to divide the price variable into two groups, depending on the number of years elapsed after the introduction of UBP. Controlling the other demographic factors, they found that the price effect lasts more than 10 years on average. However, they have a problem of identification in terms of two variables: magnitude of bag price and number of years elapsed, because they used a dummy taking the value 1 if the municipality introduced UBP more than T years earlier, and 0 otherwise. As a result, their long-run reduction effect contains an effect of price and an effect of years passed. A more serious problem is the endogeneity problem discussed in the subsection on short-run studies. To sum up, these long-run studies have some serious problems, such as sample representativeness, uncontrolled demographic change, and the endogeneity issue.

Some studies used a panel data analysis to estimate the long-run effect while avoiding such problems. Linderhof et al. (2001) is the first study that used a panel data set to estimate the effect of UBP. They used panel data for all households in a Dutch municipality in order to estimate the short-run as well as the long-run price effects through weight-based pricing (WBP) for the amounts of both compostable and non-recyclable household waste. They found evidence that the long-term price elasticity was 30 % more elastic than its short-term counterpart; moreover, they concluded that the long-term effect of WBP in compostable waste would sustain in the future. They explained that the introduction of WBP boosted people's environmental awareness, and people composted waste rather than putting it out on the curbside.

The study by Dijkgraaf and Gradus (2009) presumed a long-run effect with regard to total waste, unsorted waste, compostable waste, and recyclables using the panel data of municipalities in The Netherlands. They specified the continuity of reduction by applying a dummy variable, as Yamakawa and Ueta (2002) had; that is, 1 for all years for each municipality that introduced a UBP system in year t. Moreover, they estimated the environmental activism effect, and it was decreasing over time, which means the most environment-friendly municipalities implemented UBP or WBP pricing systems the earliest. In addition, they showed that the volume effects of the different UBP systems were rather stable over time. These 2001 and 2009 studies are summarized in Table 2.

These long-run panel studies, however, involve a few problems of their own. First of all, the study may have a problem of randomization bias.[5] Oostzaan, which they chose as the survey field, was the first municipality to introduce WBP in The Netherlands. This can be a source of bias, since households in that setting are more eager to cooperate in waste reduction; there could be endogeneity in choosing the WBP policy.[6] This would lead to long-run estimates tending to be upper-biased because Oostzaan citizens may be more environment-conscious.

5 Randomization bias in social experiment is a situation in which the experimental sample is different from the population of interest because of randomization (Levitt and List 2009).

6 Linderhof et al. (2001) said that "The largest political party in Oostzaan is Groen Links (Green Left), which is the most environmentally orientated political party in The Netherlands."

Table 2 Literature survey: short-run and long-run effects of unit-based pricing

Study	Linderhof et al. (2001)	Dijkgraaf and Gradus (2009)
Geographical region	Household data, Oostzaan, The Netherlands	Municipalities, The Netherlands
Dependent variable	Compostable and non-recyclable waste	Total waste, unsorted, compostable, and recyclable
Number of periods	Monthly panel data (42 months)	Yearly panel data (8 years)
Pricing data: dummy or actual?	Actual	Dummy variable
Type of pricing	Weight-based pricing	Weight/bag/frequency/ volume-based pricing
Years of UBP	No, but using lagged dependent variable	Year dummy: 1,2, ,,, , over 8 years
Evidence	Compostable waste: short-run elasticity: −1.10, long-run elasticity −1.39	Total waste introduced bag pricing: short-run reduction effect is smaller than long-run (more than 7 years) reduction effect
	Non-recyclable waste: short-run elasticity: −0.26, long-run elasticity −0.34	

A second problem concerns the validity of dynamic panel analysis: the approach is valid only when the price changes frequently, yet to our knowledge the price seldom changes once a pricing system starts.[7] Therefore the elasticity of their estimates may be overestimated.

Dijkgraaf and Gradus (2009) have some of the same problems Yamakawa and Ueta (2002) have. They only showed the long-run effect of WBP and UBP by means of dummy variables. To use dummy variables for the pricing period is not good because it mixes together the effect of the price dummy and the effect of the year dummy. So they cannot separate the price effect and the long-run effect.

Note that we have been referring to previous studies with regard to short-run and long-run price effects. Short-run studies have mainly been interested in detecting evidence of the substitution effect of UBP, using techniques for overcoming the endogeneity problem; however, few studies have focused on examining the source-reduction effect of UBP. Long-run studies have mainly been interested in identifying the number of years for which the waste substitution effect continues.

Our estimation strategy is to use a method for testing the Environmental Kuznets Curve (EKC) hypothesis. This enables us to interpret the results, both short-run and long-run, simultaneously. Using panel data, we can separate the effect of the price level of UBP and the effect of the number of years elapsed.

We also consider the problems of previous studies, such as Linderhof et al. (2001) and Dijkgraaf and Gradus (2009). Firstly, we adopt panel data for every city in Japan regardless of whether it has introduced UBP or not, whereas Linderhof et al. used only one municipality's data. Secondly, we use actual bag price data and its introduced year data, whereas Dijkgraaf and Gradus (2009) used only a dummy variable of introduction.

[7] In Japan the bag price introduced in 1995 stayed unchanged up to 2002 in all the municipalities where it was introduced.

It is also important to point out that this paper is the first study to clarify why the long-run price effect, including the reduction and substitution effects, continues or not. In particular, we compare the difference in long-run effects between income groups. Because of differences in opportunity cost of time or environmental awareness, there might be heterogeneity in their rebound effect.

2 Estimation Strategy

In this section we show our strategy to estimate the short-run and long-run reduction and substitution effects of the UBP policy to affect household demand for a waste collection service. We employ a regression model of a panel data analysis, and apply a fixed-effect model. By doing this we can correct the bias caused by an omitted variable, such as the introduction of a price and a recyclables collection, which have been perceived as being endogenous in cross-section models.[8]

First of all, we need to split the short-run and long-run effects of UBP on waste collection. We define the explanatory variable, $\ln p$, as the natural log of bag price per bag or tag (yen per 40–50 l bag), and y represents the number of years that have elapsed since the introduction of UBP, which is important to detect the short-run and long-run reduction effects (because they are believed to be dependent on the years that have elapsed since the introduction of UBP). To capture the dynamic effect of UBP, we borrow the method used to test empirical evidence for the existence of an EKC hypothesis (Dinda 2004), and introduce interaction terms of $\ln p$ times y and $\ln p$ times y squared. We define the demand for a waste collection service and assume a double log model as follows:

$$\ln w_{sit} = \alpha + \beta_1 \ln p_{it} + \beta_2 \ln p_{it} \times y_{it} + \beta_3 \ln p_{it} \times y_{it}^2 + \gamma' Z_{it} + a_i + \lambda_t + u_{it} \quad (1)$$

where the dependent variable, $\ln w_s$, is the natural log of the amount of s types of waste per capita per day (in g), whose s is total waste, unsorted waste, or recyclable waste; Z is a vector of other demographic variables that have an influence on waste generation. Further, the subscripts i and t indicate the municipality and the time, respectively; a and λ are the unobserved heterogeneity that is invariant across time and cross-section change, respectively; β and γ' are parameters and a parameter vector, respectively, in this linear model. We assume the error term u is normally and independently distributed with mean zero and variance σ^2.

If we partially differentiate $\ln w_s$ with respect to $\ln p$ in Eq. 1, we get the price elasticity of demand for s types of waste collection service, ϵ,

$$\frac{\partial \ln w_s}{\partial \ln p} = \epsilon = \beta_1 + \beta_2 y + \beta_3 y^2. \quad (2)$$

Note that this elasticity depends on the number of years and its square. We can give a diagnosis using estimated signs of parameters. For example, there is a rebound effect of waste reduction if the signs of parameters are ($\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 = 0$), ($\beta_1 < 0$, $\beta_2 = 0$ and $\beta_3 > 0$), or ($\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 > 0$); there is a monotonically increasing relationship or a linear relationship between $\partial \ln w / \partial \ln p$ and y. This implies that the price elasticity is decreasing with years (a rebound effect). To judge how shapes validate in the long run, an F test and t test are applied to estimated parameters. We confirm them in Sect. 4.

[8] A fixed-effect model is not free of problems. Another type of endogeneity problem might arise if there is spatial dependency in the introduction of the waste policy. To correct this bias, Allers and Hoeben (2010) have dealt with the spatial autocorrelation. We know the importance of such a strategy, but we cannot apply that estimation method. Since we use only city-level data, the adjacency relation among municipalities is imperfect. Our study is, therefore, obliged to abandon the correction of spatial autocorrelation. However, municipal fixed effects may partly mitigate this type of endogeneity problem.

We also test the endogeneity with relation to bag price variables. Kinnaman and Fullerton (2000), Callan and Thomas (2006), and Allers and Hoeben (2010) have controlled the selection bias arising from the introduction of bag price variables by introducing appropriate instrumental variables. Certainly, a panel data analysis partially alleviates the selection bias that arises from a "time-invariant" omitted variable—for instance, the environmental consciousness of households. However, it cannot control "time-variant" omitted variables. We discuss this issue further in Sect. 5.1.

3 Data

In this section we define the dependent and other demographic variables and then explain our panel data.

3.1 Definition of the Dependent Variable

We want to clarify the short-run and long-run effects of waste reduction and waste recycling by citizens. To examine this, we focus on different types of waste, namely total waste, unsorted waste, and recyclable waste. We use the amount of these three types of waste per capita per day as our dependent variable.

3.1.1 Total Waste Generation

UBP will bring about waste reduction, so we analyze its effect by defining waste generation as the dependent variable. Total waste generation is the sum of combustible waste, noncombustible waste, and recyclables collected by citizens. In the UBP literature, the papers that clarified the reduction effect of total waste generation are Houtven and Morris (1999), Dijkgraaf and Gradus (2004, 2009), and Allers and Hoeben (2010). Of the long-run studies, Dijkgraaf and Gradus (2009) is the only one that examines the reduction effect of total waste.

3.1.2 Unsorted and Recyclable Waste

We also define unsorted waste and recyclable waste in order to analyze the amount of unsorted waste redirected into recyclable waste in the short run and long run. Unsorted waste is composed of combustible waste and noncombustible waste. Recyclable waste is composed of glass bottles, plastic containers and packagings, PET bottles, cans (aluminum and steel cans), and paper containers and packaging. Data on the amount of recycling in each municipality has been available since 1995, before the Containers and Packaging Recycling Law was implemented in 1997. Normally a bag price is levied on unsorted waste but not on recyclable waste.

3.2 Demographic Variables

Demographic variables consist of: income per capita, population density, household size, age structure, and other price dummy. ln *Popd* represents the population density (persons/km^2). This variable will be a proxy of housing space, since it is more difficult to stock recyclable waste in a smaller house. ln *Income* represents taxable income per capita (in 1995 Japanese yen). This can be regarded as a proxy for the amount of consumption and time cost to work on waste separation. In *Family*, the household size, may include some merit of scale in regard to consumption, because a large household size will decrease per capita consumption of shared goods such as newspapers, and therefore waste generation. Further, *Under 4* and *Over 65* represent the ratios of population in each municipality under age 4 and over age 65, respectively. D_{Paper}, D_{Metal}, D_{Glass}, D_{PET}, $D_{Plastic}$, D_{Other} are dummy variables that take 1 when a city has a recycle program for paper, metal, glass, PET bottles, plastic containers, and other material. $D_{Misccharge}$ is a dummy variable that takes 1 when a city is introducing some kind of charge for waste collection other than UBP—for example, a fixed monthly fee. We cannot introduce educational variables that become a proxy for the intelligence of citizens, because such data is unavailable. Although anecdotal evidence suggests that municipalities took steps (such as information provision), to avoid any rebound effect of UBP, data on these additional policies are unavailable, so we are not able to identify their effect on long-run price responsiveness. Monetary variables, p and *Income*, are needed to control for the effects of inflation or deflation; we adjust for inflation using the FY 1995 consumer price index.

3.3 Data Sources

We merged three categories of municipal panel data: (1) waste data, (2) bag price data, and (3) demographic data. First, we used data on 712 cities taken from data on 3,200 municipalities provided by the Japan Waste Management Association (1995–2002)—data pertaining to the total waste, unsorted waste, and recyclable waste for each city spanning an 8-year period from fiscal years 1996 to 2002.

Second, we used the data on waste pricing and the year each city introduced UBP gathered by Yamaya (2006). Yamaya worked out a comprehensive survey for all 712 cities and the 23 wards of Tokyo by means of questionnaires administered through the mail and by telephone in February 2005. For cities that were adopting UBP, he also asked the price of garbage bags for 40–50l of waste per garbage bag or a corresponding tag used to levy a fee on the waste generated.

Figure 2 presents a histogram of the data for such prices. The vertical axis represents the number of cities, and the horizontal axis represents the price per 40–50l of waste per

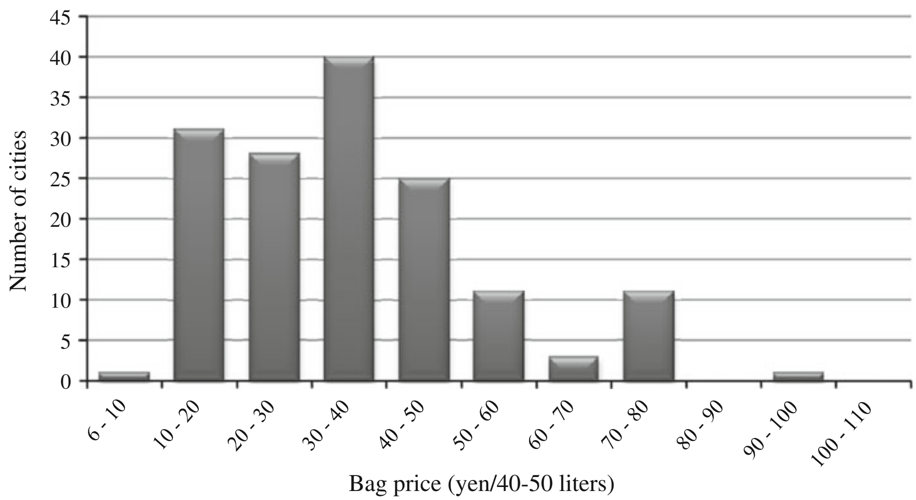

Fig. 2 Histogram of bag prices

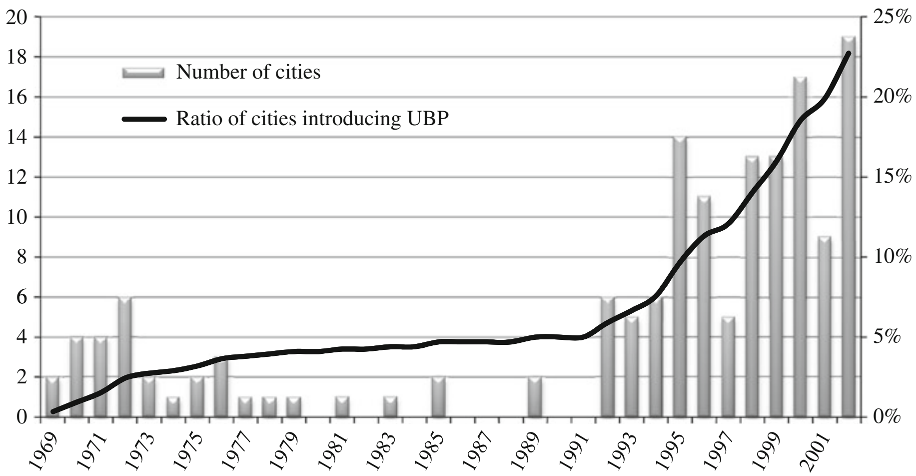

Fig. 3 Histogram of years UBP was introduced

garbage bag.[9] The histogram shows that the mode is 30–40 yen per bag, and the median is also the same. Mostly UBP is implemented for combustible and noncombustible waste. The price level for municipalities without UBP is set at 5 cents per bag, because people must buy bags to dispose of their waste (Usui 2008). Figure 3 presents a histogram of the years when UBP was introduced; the vertical axis on the left side gives the number of cities and the right side gives the percentage of cities that introduced UBP; the horizontal axis represents the year of introduction. The number of cities adopting UBP increases steadily, and 23 % of them have introduced UBP. Finally, other demographic data was obtained from *Minryoku* (Asahi Shimbun 2003), which is a collective database containing data for all municipalities.

The descriptive statistics and the definitions of the variables are presented in Table 3. A total of 712 cities are used as the population for this study. We have used 8 years of data, from FY 1996 to 2002. This is because data on waste generation became available after 1996 and there has been a considerable increase in municipal mergers after 2002. Excluding missing values, we used 665 (cities) × 7 (years) unbalanced panel data for estimation.

4 Estimation Result

We estimate Eq. (1) by applying the panel model. In our discussion of the estimation results, we only consider the fixed-effect estimates.[10] Standard errors in the model are robust to heteroskedasticity and clustered by municipality (of which there were 665).

[9] The currency exchange rate is as follows: 100 Japanese yen equals approximately 1 euro.

[10] We carefully chose our panel model from among three models: pooled OLS, fixed-effect, and random-effect. We employed systematic model selection, lest the wrong model generate inconsistent estimates. We also used the F test, the Breusch–Pagan Lagrange Multiplier test (BP test), and the Hausman test (see Hsiao 2002). Our test strategies were: (1) to choose between the pooled OLS and fixed-effect models, we applied the F test; (2) to choose between the pooled OLS and random-effect models, we applied the BP test; (3) to choose between the fixed-effect and random-effect models, we applied the Hausman test. In the end we selected the fixed-effect model.

Table 3 Estimation results: total waste, unsorted waste, and recyclable waste

Variable	Mean	S.D.	Min	Max	Definition	N
$\ln w_{total}$	6.84	0.22	5.54	7.65	Natural log of volume of total waste collection per capita per day (g)	5,314
$\ln w_{unsorted}$	6.69	0.25	4.02	7.64	Natural log of volume of unsorted waste collection per capita per day (g)	5,314
$\ln w_{recyclable}$	4.67	0.72	−1.65	6.75	Natural log of volume of recyclable collection per capita per day (g)	5,250
$\ln p$	1.90	0.75	1.54	4.66	Natural log of price per bag or tag (yen per 40–501)	5,320
$\ln p \times y$	5.21	18.66	0	124.91	Natural log of price × number of years since the introduction of the unit-based pricing	5,320
$\ln p \times y^2$	106.71	483.17	0	4,121.89	Natural log of price × squared number of years	5,320
$D_{Misccharge}$	0.04	0.19	0	1	Dummy for other pricing scheme than UBP	5,320
D_{Paper}	0.65	0.48	0	1	Dummy for collecting papers	5,320
D_{Metal}	0.83	0.38	0	1	Dummy for collecting metals	5,320
D_{Glass}	0.82	0.38	0	1	Dummy for collecting glasses	5,320
D_{PET}	0.49	0.50	0	1	Dummy for collecting PET bottles	5,320
$D_{Plastic}$	0.17	0.38	0	1	Dummy for collecting plastic containers	5,320
D_{Other}	0.42	0.49	0	1	Dummy for collecting other recyclables	5,320
$\ln Popd$	6.66	1.29	2.96	9.53	Natural log of population density (person/km^2)	5,313
$\ln Family$	0.29	0.22	−0.50	1.02	Natural log of average household size	5,313
$\ln Income$	4.90	0.22	4.11	5.63	Natural log of income per capita (10 thousand yen)	5,313
$Under\ 4$	0.05	0.01	0.02	0.08	The ratio of population under 4 ages	5,313
$Over\ 65$	0.17	0.05	0.06	0.36	The ratio of population over 65 ages	5,313
$\ln diff\_w_{total t-2}$ $\ln diff\_w_{total t-1}$	0.02	0.07	−0.63	0.73	Difference of natural log of volume of total waste collection per capita per day (g) : 2-year lag minus 1-year lag	3,984
$\ln Capind_{t-1}$	−0.43	0.40	−2.30	0.49	Natural log of lag of financial capability index	4,648
$D_{inc,t-1}$	0.95	0.22	0	1	Lag of dummy variable of incineration facility possession	3,325

4.1 Testing Endogeneity

This section explains the strategy used to test for endogeneity of a UBP policy. Though the test result shows some evidence of endogeneity, the estimated results do not support the appropriateness of instrumental variables (IV). We tried several variables as candidates for instrument, including difference in total waste collection, the possession of an incineration facility, and the financial capacity of the municipality. The test statistics of the underidentification test (Kleibergen and Paap 2006) are calculated using a Lagrange Multiplier test. The null hypothesis is that the equation is underidentified—to be more precise, the matrix of reduced form coefficients has rank $= k_1 - 1$, where k_1 is the number of endogenous regressors. The Lagrange Multiplier statistics are not statistically significant for all equations. Thus the results show these equations are underidentified.

Because of the unavailability of appropriate instruments, we employ OLS in our analysis while dealing with the possible endogeneity of price variable by using its lagged value in our estimation. Furthermore, to consider the bias caused by any omitted variable, we include three different proxy variables. First is a change in recycling policy. The variable $diff_{rec}$ takes value one when there is a change at least one item in the recyclable collection that has been changed compared to the previous year, and zero otherwise. We interact $diff_{rec}$ with the price variables. It hopefully captures the impact of any supplemental policy introduced together with UBP. The second and third proxy variables are dummy variables to control the announcement effect. Since local residents are informed of the introduction of UBP at least 1 year in advance, there will be some impact on their environmental consciousness either as a result of provision of information or by active promotion of waste reduction even before the introduction.

We employed five models as follows: a baseline model (Model 1); a model with a 1-year lagged price variable (Model 2); a model with a cross-term between the price variable and the proxy variable for policy change (Model 3); a model with a dummy variable that takes value one when it is 1 year before the introduction of a UBP policy (Model 4); and a model with a dummy variable that takes value one when it is 1 year before the introduction of a UBP policy, within the year of the introduction, or 1 year after the introduction (Model 5). Although these attempts to deal with enodogeneity are not perfect, we can control biases caused by an omitted variable to some extent.

Tables 4, 5, and 6 show our estimation results. Results are similar among these models. The estimation result of Model 2 is almost the same as that of the baseline model. We do not find evidence of an announcement effect from a UBP policy on waste reduction (Model 4). While we find evidence of an announcement effect for the recyclable collection, the magnitude of the short-run and long-run effects of the UBP policy is similar to that of the baseline model. Therefore, we conclude that any bias that might be caused by an omitted variable is not serious. Hereafter, we confine our discussion to the baseline model (Model 1) for each category of waste.

4.2 Fixed-Effect Model

First, we show the test result of the long-run effect. The estimation result indicates that long-run elasticity was gradually eroding in total waste and unsorted waste, while an inverted U-shaped relationship was found in recyclable waste as more and more years elapsed since UBP's introduction. First of all, we consider the three price variables: $\ln p$, $y \times \ln p$, and $y^2 \times \ln p$. Since F-statistics in total waste, $F(3, 664) = 17.7$, are sufficient to reject the null hypothesis, $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$, at the conventional level of significance, we

Table 4 Estimation results of fixed-effect model: total waste

Variables	(1)	(2)	(3)	(4)	(5)
ln p	−0.038***		−0.040***	−0.040***	−0.036***
	(0.007)		(0.007)	(0.008)	(0.007)
ln $p \times y$	−0.000004		−0.000001	−0.000005	−0.000015
	(0.000018)		(0.000018)	(0.000017)	(0.000020)
ln $p \times y^2$	0.000003***		0.000003***	0.000003***	0.000004***
	(0.000001)		(0.000001)	(0.000001)	(0.000001)
ln p_{t-1}		−0.032***			
		(0.006)			
ln $p_{t-1} \times y_{t-1}$		0.000034			
		(0.000021)			
ln $p_{t-1} \times y_{t-1}^2$		0.000002**			
		(0.000001)			
ln $p \times \mathit{diff}_{rec}$			0.003		
			(0.002)		
ln $p \times y \times diff_{rec}$			−0.000002		
			(0.000012)		
ln $p \times y^2 \times diff_{rec}$			0.0000001		
			(0.00000036)		
$D_{year,t-1}$				−0.011	
				(0.017)	
D_{3years}					−0.009
					(0.011)
ln *Popd*	−0.038	−0.042	−0.038	−0.038	−0.037
	(0.072)	(0.073)	(0.072)	(0.072)	(0.071)
ln *Income*	0.213**	0.189*	0.214**	0.215**	0.213**
	(0.100)	(0.101)	(0.099)	(0.100)	(0.100)
ln *Family*	0.015	0.003	0.011	0.016	0.014
	(0.180)	(0.179)	(0.179)	(0.181)	(0.180)
Under 4	−2.502***	−2.496***	−2.517***	−2.513***	−2.505***
	(0.698)	(0.696)	(0.700)	(0.704)	(0.700)
Over 65	−2.318***	−2.490***	−2.304***	−2.290***	−2.295***
	(0.850)	(0.865)	(0.849)	(0.836)	(0.841)
$D_{mischarge}$	−0.004	−0.005	−0.003	−0.003	−0.003
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
D_{Paper}	−0.001	−0.001	−0.001	−0.001	−0.001
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
D_{Metal}	0.006	0.005	0.006	0.006	0.007
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
D_{Glass}	0.001	0.001	0.001	0.001	0.001
	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)
D_{PET}	−0.005	−0.005	−0.006	−0.005	−0.005
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)

Table 4 continued

Variables	(1)	(2)	(3)	(4)	(5)
$D_{Plastic}$	−0.012**	−0.012**	−0.012***	−0.012**	−0.012**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
D_{Other}	−0.004	−0.005	−0.003	−0.003	−0.003
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
Year 97	0.016**	0.018**	0.021**	0.016**	0.016**
	(0.007)	(0.008)	(0.008)	(0.007)	(0.007)
Year 98	0.051***	0.053***	0.055***	0.051***	0.051***
	(0.013)	(0.013)	(0.014)	(0.013)	(0.013)
Year 99	0.082***	0.084***	0.084***	0.082***	0.082***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Year 00	0.118***	0.119***	0.122***	0.118***	0.117***
	(0.022)	(0.023)	(0.023)	(0.022)	(0.022)
Year 01	0.146***	0.148***	0.149***	0.146***	0.146***
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Year 02	0.158***	0.158***	0.160***	0.158***	0.157***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
Constant	6.558***	6.700***	6.557***	6.549***	6.554***
	(0.624)	(0.631)	(0.624)	(0.623)	(0.623)
N	4,644	4,644	4,644	4,644	4,644
Adjusted R^2	0.234	0.223	0.235	0.235	0.235
Groups	665	665	665	665	665

Standard errors are in parentheses and are all corrected for statistics robust to heteroskedasticity and clustered by municipality (of which there were 665)
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

reject it. Likewise, F-statistics in unsorted waste, $F(3, 664) = 23.4$, and recyclable waste, $F(3, 664) = 9.0$, are also statistically significant.

Since the estimated result shows $\beta_1 < 0$, $\beta_2 = 0$, and $\beta_3 > 0$, there is a monotonically increasing relationship between long-run elasticity and number of years elapsed: the more years that pass after the introduction of UBP, the more the waste reduction effect erodes. These results mean there are rebound effects with respect to total waste and unsorted waste. Meanwhile, the long-run price elasticity in recyclable waste shows a U-shaped relationship between $\partial \ln w / \partial \ln p$ and y. This implies that the long-run elasticity of recyclable waste seems to gradually decrease for up to 16 years, then gradually increase. This suggests a mixed effect: that the learning effect becomes stronger than awareness erosion in the long run. These results suggest that recycling is successfully promoted by adoption of UBP and a recycling law, while reduction of total waste generation is weak because UBP seems ineffective in changing people's purchasing behavior.

Figure 4 shows the predicted values of elasticity for total waste, unsorted waste, and recyclable waste calculated on the basis of Eq. 2. The vertical axis represents the price elasticity of total waste, unsorted waste, and recyclable waste, and the horizontal axis is the number of years that have passed since the price policy was introduced. The predicted values of curves are, as calculated above, gradually increasing in total waste and unsorted waste, but they do not seem to exhaust the price elasticity of waste generation even over 30 years.

Table 5 Estimation results of fixed-effect model: unsorted waste

Variables	(1)	(2)	(3)	(4)	(5)
ln p	−0.058***		−0.060***	−0.063***	−0.054***
	(0.008)		(0.008)	(0.009)	(0.008)
ln $p \times y$	0.000024		0.000031	0.000021	0.000005
	(0.000022)		(0.000022)	(0.000022)	(0.000025)
ln $p \times y^2$	0.000003***		0.000003**	0.000003***	0.000003***
	(0.000001)		(0.000001)	(0.000001)	(0.000001)
ln p_{t-1}		−0.048***			
		(0.008)			
ln $p_{t-1} \times y_{t-1}$		0.000085***			
		(0.000025)			
ln $p_{t-1} \times y_{t-1}^2$		0.0000017			
		(0.000001)			
ln $p \times diff_{rec}$			0.003		
			(0.002)		
ln $p \times y \times diff_{rec}$			−0.000013		
			(0.000015)		
ln $p \times y^2 \times diff_{rec}$			0.0000006		
			(0.00000048)		
$D_{year,t-1}$				−0.029	
				(0.021)	
D_{3years}					−0.016
					(0.013)
ln *Popd*	−0.051	−0.058	−0.050	−0.050	−0.049
	(0.061)	(0.063)	(0.061)	(0.061)	(0.060)
ln *Income*	0.177	0.141	0.177	0.182	0.176
	(0.121)	(0.123)	(0.121)	(0.122)	(0.122)
ln *Family*	0.057	0.040	0.053	0.060	0.055
	(0.190)	(0.189)	(0.189)	(0.190)	(0.189)
Under 4	−2.135**	−2.130**	−2.147**	−2.164**	−2.141**
	(0.869)	(0.868)	(0.871)	(0.874)	(0.871)
Over 65	−3.965***	−4.213***	−3.956***	−3.895***	−3.927***
	(0.969)	(0.988)	(0.967)	(0.950)	(0.957)
$D_{misccharge}$	−0.021	−0.023	−0.020	−0.020	−0.020
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
D_{Paper}	−0.017**	−0.016*	−0.017**	−0.017**	−0.017**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
D_{Metal}	−0.010	−0.012	−0.010	−0.010	−0.010
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
D_{Glass}	−0.008	−0.008	−0.008	−0.009	−0.009
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
D_{PET}	−0.014**	−0.014**	−0.015**	−0.014**	−0.014**
	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)

Table 5 continued

Variables	(1)	(2)	(3)	(4)	(5)
$D_{Plastic}$	−0.032***	−0.032***	−0.032***	−0.032***	−0.032***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
D_{Other}	−0.021	−0.023	−0.020	−0.020	−0.020
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
Year 97	0.019**	0.021**	0.022**	0.019**	0.018**
	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)
Year 98	0.065***	0.067***	0.068***	0.064***	0.064***
	(0.015)	(0.015)	(0.016)	(0.015)	(0.014)
Year 99	0.100***	0.103***	0.102***	0.100***	0.100***
	(0.019)	(0.020)	(0.020)	(0.019)	(0.019)
Year 00	0.134***	0.135***	0.138***	0.133***	0.133***
	(0.026)	(0.026)	(0.027)	(0.026)	(0.026)
Year 01	0.170***	0.172***	0.172***	0.170***	0.170***
	(0.032)	(0.033)	(0.033)	(0.032)	(0.032)
Year 02	0.186***	0.185***	0.188***	0.185***	0.185***
	(0.039)	(0.039)	(0.039)	(0.038)	(0.038)
Constant	6.824***	7.033***	6.825***	6.800***	6.818***
	(0.778)	(0.783)	(0.779)	(0.778)	(0.779)
N	4,644	4,644	4,644	4,644	4,644
Adjusted R^2	0.112	0.097	0.113	0.114	0.113
Groups	665	665	665	665	665

Standard errors are in parentheses and are all corrected for statistics robust to heteroskedasticity and clustered by municipality (of which there were 665)
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Likewise, though the estimated result suggests an inverted U-shaped line for recyclable waste, it appears as a straight line, at least within the 30 years of the actual sample range. This result is in line with the empirical findings of Yamakawa and Ueta (2002) and Dijkgraaf and Gradus (2009). For example, Yamakawa and Ueta (2002) found that the reduction effect of UBP on unsorted waste sustains at least 10 years. Dijkgraaf and Gradus (2009) also suggest that the reduction effect of total waste sustains over 7 years.

The estimation results are given in Tables 4, 5, and 6. In summary, we find that models on total waste and unsorted waste have the same signs for all variables. The population density does not have a significant effect in any equation. The coefficients of income per capita (ln *Income*) are statistically significant at the conventional level of significance and positive in total waste and recyclable waste equations. The variable is affected by many channels: (1) it is a proxy for the opportunity cost of time (negative relation with waste generation); (2) it is a proxy for the amount of consumption (positive relation with waste generation); and (3) it might be a proxy for the level of education level.[11] As a result of these channels, the sign of the coefficient is positive in total waste and recyclable waste equations. The average household size in each city, ln *Family*, is not significant in any equation. The coefficient of

[11] Because of a lack of data with respect to education levels in Japanese cities, we cannot control for the effect of educational level on waste generation.

Table 6 Estimation results of fixed-effect model: recyclable waste

Variables	(1)	(2)	(3)	(4)	(5)
ln p	0.119***		0.125***	0.135***	0.121***
	(0.028)		(0.027)	(0.031)	(0.029)
ln $p \times y$	−0.000259***		−0.000271***	−0.000249***	−0.000263***
	(0.000086)		(0.000087)	(0.000086)	(0.000093)
ln $p \times y^2$	0.000008		0.000008*	0.000008	0.000008
	(0.000005)		(0.000005)	(0.000005)	(0.000006)
ln p_{t-1}		0.092***			
		(0.031)			
ln $p_{t-1} \times y_{t-1}$		−0.000377***			
		(0.000079)			
ln $p_{t-1} \times y_{t-1}^2$		0.000011**			
		(0.000005)			
ln $p \times diff_{rec}$			−0.082		
			(0.008)		
ln $p \times y \times diff_{rec}$			0.000026		
			(0.000057)		
ln $p \times y^2 \times diff_{rec}$			−0.0000004		
			(0.0000020)		
$D_{year,t-1}$				0.098*	
				(0.058)	
D_{3years}					−0.004
					(0.050)
ln *Popd*	0.157	0.173	0.156	0.154	0.157
	(0.183)	(0.179)	(0.183)	(0.182)	(0.183)
ln *Income*	1.020*	1.089*	1.022*	1.007*	1.020*
	(0.561)	(0.558)	(0.560)	(0.560)	(0.561)
ln *Family*	−0.395	−0.371	−0.380	−0.404	−0.395
	(0.813)	(0.819)	(0.815)	(0.811)	(0.813)
Under 4	−11.272***	−11.239***	−11.214***	−11.174***	−11.274***
	(3.783)	(3.778)	(3.775)	(3.756)	(3.784)
Over 65	12.772***	13.244***	12.789***	12.514***	12.781***
	(3.645)	(3.618)	(3.648)	(3.672)	(3.673)
$D_{misccharge}$	0.144***	0.149***	0.141***	0.142***	0.144***
	(0.053)	(0.053)	(0.053)	(0.052)	(0.052)
D_{Paper}	0.149***	0.146***	0.149***	0.150***	0.149***
	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)
D_{Metal}	0.128**	0.130**	0.129**	0.128**	0.128**
	(0.060)	(0.060)	(0.060)	(0.060)	(0.060)
D_{Glass}	0.251***	0.252***	0.251***	0.252***	0.251***
	(0.063)	(0.063)	(0.063)	(0.063)	(0.062)
D_{PET}	0.045*	0.046*	0.048*	0.045*	0.045*
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)

Table 6 continued

Variables	(1)	(2)	(3)	(4)	(5)
$D_{Plastic}$	0.077***	0.078***	0.078***	0.078***	0.077***
	(0.024)	(0.024)	(0.025)	(0.024)	(0.024)
D_{Other}	0.144***	0.149***	0.141***	0.142***	0.144***
	(0.053)	(0.053)	(0.053)	(0.052)	(0.052)
Year 97	−0.029	−0.034	−0.040	−0.029	−0.029
	(0.035)	(0.034)	(0.036)	(0.035)	(0.035)
Year 98	−0.113*	−0.117**	−0.124**	−0.112*	−0.113*
	(0.058)	(0.057)	(0.059)	(0.058)	(0.058)
Year 99	−0.132	−0.136*	−0.137*	−0.131	−0.132
	(0.081)	(0.080)	(0.080)	(0.081)	(0.081)
Year 00	−0.091	−0.091	−0.102	−0.089	−0.091
	(0.109)	(0.108)	(0.108)	(0.109)	(0.109)
Year 01	−0.112	−0.115	−0.118	−0.110	−0.112
	(0.138)	(0.138)	(0.137)	(0.138)	(0.139)
Year 02	−0.170	−0.168	−0.176	−0.168	−0.171
	(0.171)	(0.171)	(0.170)	(0.171)	(0.171)
Constant	−0.906	−1.285	−0.935	−0.839	−0.906
	(3.507)	(3.491)	(3.504)	(3.498)	(3.508)
N	4,603	4,603	4,603	4,603	4,603
Adjusted R^2	0.375	0.373	0.375	0.376	0.375
Groups	665	665	665	665	665

Standard errors are in parentheses and are all corrected for statistics robust to heteroskedasticity and clustering by municipality (by each of the 665 number of municipalities are 665 municipalities)
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

the average household size ln *Family* is positive, but our result is not statistically significant. The ratio of the population variable *Under 4*, is significant and negative in all equations. The coefficients of *Under 4* for total waste and that for recyclable waste are both negative signs. This result suggests that households with children under age 4 are relatively better at waste reduction than at recycling. The ratio of the population variable *Over 65* is significant in all equations, and negative in the total waste and unsorted waste equations but positive in the recyclable waste equation. This result suggests that retired people may have considerably more free time and can therefore reduce waste and separate out recyclable waste objects.

In the equations of recyclable waste, we find all collection dummy variables are statistically significant and positive. These results suggest that there is an evidence of a willingness to contribute to recycling activities. Dummy variables of recyclable materials capture the effect of a recycling policy independent of any economic incentive produced by UBP. We find the coefficient of the collection dummy for plastic containers is statistically significant and negative in total waste and unsorted waste. This effect may be of interest to public administrators. It means that there is a voluntary reduction effect in total waste, because people reduce their purchases of, or refuse to purchase, plastic containers and packaging, even without an economic incentive, while in unsorted waste, this effect is interpreted as the result of reduction and substitution effects. It is important that PET dummy and paper container dummy are statistically significant and negative in unsorted waste equation, meanwhile not

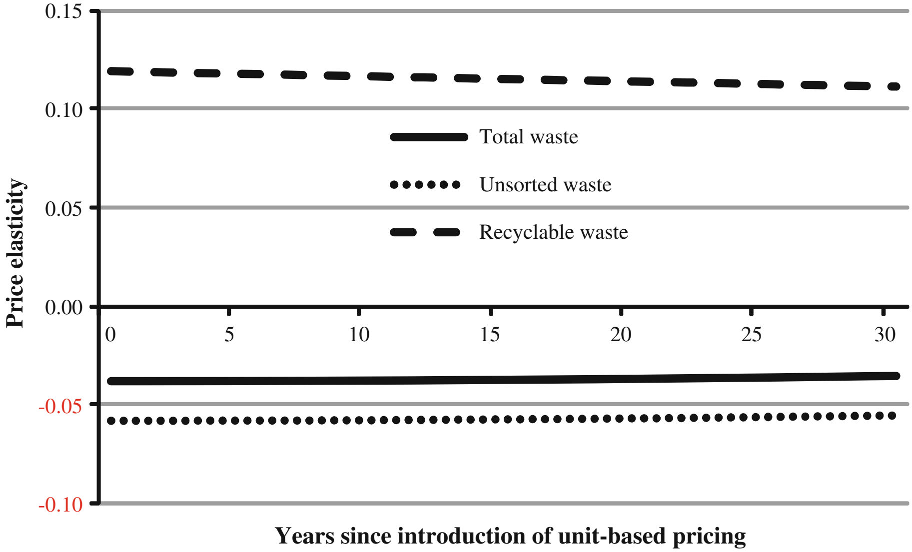

Fig. 4 Predicted values of long-run price elasticities. *Note* Predicted values are based on Model 1 of Tables 4, 5, and 6

statistically significant in total waste. These results can be interpreted as an indication that recycling of these containers can promote collection of recyclables without any economic instruments, while it might not contribute to waste reduction.

All the year dummies are significant and positive in total waste and unsorted waste (compared to the baseline of *Year 96*), but not significant in recyclable waste collection. These results suggest a trend toward a gradual increase in waste generation, while recyclable waste is constant in comparison with the flow of waste generation. To sum up, our results show that there is a rebound effect in waste generation, but the size of the effect is considerably small.

5 Discussion

5.1 Split Sample Analysis

In this section we focus on income level as a possible factor affecting waste generation and recyclable collection in different ways, in the short and long run, because these activities may be affected by opportunity cost, or education level, as discussed in the variable of income per capita in Sect. 4. It is plausible that those who earn a high income do not respond to the bag price with activities aimed at recycling, because time cost may be relatively higher. On the other hand, those who earn high incomes have a higher level of education, so they may be willing to join such activities. In order to check this, we divide our sample into high and low income based on the median value of average per capita income of 665 municipalities in 2002. We use OLS with the fixed-effect model described in Sect. 4 and apply it to each income group. To sum up the estimation results: the high-income group responds to the bag price through waste reduction activity (both short- and long-run), but not through recycling activity, while the low-income group prefers recycling activity over the long run, but does not continue waste reduction over the long run.

In Table 7 the first, third, and fifth columns are the coefficients and standard errors of the high-income group, and the second, fourth, and sixth columns show those of the low-income group.[12] The results for the total waste and unsorted waste equations are basically the same as those of Sect. 5. We do not find a large difference between the two income groups. The estimated result shows $\beta_1 < 0$, $\beta_2 = 0$, and $\beta_3 > 0$. This means that there is a monotonically increasing relationship between the long-run elasticity and the number of years elapsed. However, in the equation of recyclable waste (the fifth column), people who earn a high income do not react to a bag price by sorting out recyclables in the short run and do even less recycling in the long run. This is interpreted to mean that high-income people consider that the opportunity cost of time involved in recycling activity is more expensive than paying the bag price, and so they do not react to the bag price. Low-income people, on the other hand, are price elastic in the equation of recyclable waste (the sixth column), because their opportunity cost is relatively smaller than that of high-income people.

Apart from the price effect, we consider the dummy variables for recyclable waste collection. The coefficients for all recyclables except PET bottles are statistically significant. This means the high-income group voluntarily sorts recyclables regardless of the short- and long-run effects of bag price. This is important, because the evidence shows a willingness to contribute to recycling. For the low-income group, however, only the coefficients for metal cans and glass collection (sixth column) are significant. These items were being collected before UBP was introduced in most cities, and people are used to collecting them without any economic incentive. Therefore, UBP is effective for the low-income group to induce them to collect and separate other recyclables in terms of both the short run and the long run.

To sum up, our estimation results suggest that responses to recycling activities differ between income groups. For the high-income group, the activity of recycling has not been promoted through an economic incentive; they are voluntarily willing to start recycling. In contrast, recycling activity on the part of the low-income group is strongly motivated by the implementation of UBP, and they continue their recycling activity for years, stimulated by the economic incentive in the form of UBP.

5.2 Robustness Check

To check robustness, we also employed the interaction-term with $\ln p \times \ln Income$, $\ln p \times y \times \ln Income$, and $\ln p \times y^2 \times \ln Income$ and regressed for all samples.

$$\begin{aligned}\ln w_{sit} &= \alpha + (\kappa_1 \ln p_{it} + \kappa_2 \ln p_{it} \times y_{it} + \kappa_3 \ln p_{it} \times y_{it}^2) \times \ln Income \\ &\quad + \beta_1 \ln p_{it} + \beta_2 \ln p_{it} \times y_{it} + \beta_3 \ln p_{it} \times y_{it}^2 + \gamma' Z_{it} + a_i + \lambda_t + u_{it} \qquad (3)\end{aligned}$$

Table 8 shows the estimation results of the above equation. The estimated values of γ's were omitted. To sum up, results in all equations are similar to the split-sample regressions. For example, in the equation of total waste, we found evidence that price responsiveness is lower for a municipality with higher incomes. The coefficient of the $\ln p_{it} \times \ln Income$ was statistically significant and positive, which meant the absolute value of price elasticity decreased when income per capita increased. Furthermore, the coefficients of year-elapsed terms were not statistically significant.

[12] The number of observations are different between models because of missing values.

Table 7 Estimation results: total waste, unsorted waste, and recyclable waste

Variables	$\ln w_{total}$		$\ln w_{unsorted}$		$\ln w_{recyclable}$	
	High income	Low income	High income	Low income	High income	Low income
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln p$	−0.017*	−0.050***	−0.032**	−0.073***	0.034	0.140***
	(0.010)	(0.008)	(0.015)	(0.009)	(0.040)	(0.034)
$\ln p \times y$	−0.000013	−0.000015	−0.000021	0.000017	0.000003	−0.000369***
	(0.000041)	(0..000023)	(0.000055)	(0.000027)	(0.000116)	(0.000101)
$\ln p \times y^2$	0.000003**	0.000003***	0.000004*	0.000002*	−0.000012**	0.000016***
	(0.000001)	(0.000001)	(0.000002)	(0.000001)	(0.000006)	(0.000006)
ln *Popd*	−0.002	−0.034	−0.032	0.103	0.079	−0.544
	(0.037)	(0.200)	(0.035)	(0.215)	(0.178)	(1.077)
ln *Income*	0.146	0.261*	0.094	0.269*	1.531**	0.311
	(0.130)	(0.134)	(0.144)	(0.159)	(0.711)	(0.962)
ln *Family*	−0.329	0.208	−0.334	0.562	0.558	−7.753***
	(0.203)	(0.426)	(0.209)	(0.537)	(0.817)	(2.859)
Under 4	−3.526***	−1.318	−2.754	−0.618	−9.322	−21.383*
	(1.357)	(2.318)	(1.769)	(2.809)	(6.141)	(12.688)
Over 65	−4.596***	−1.200	−6.976***	−1.753	13.208***	3.300
	(1.310)	(1.121)	(1.421)	(1.266)	(4.337)	(7.658)
$D_{Misccharge}$	0.017	0.005	0.009	−0.043*	0.158**	0.365**
	(0.025)	(0.034)	(0.036)	(0.026)	(0.062)	(0.170)
D_{Paper}	0.001	0.004	−0.007	−0.011	0.137***	0.115
	(0.007)	(0.011)	(0.009)	(0.013)	(0.041)	(0.071)
D_{Metal}	0.008	−0.001	−0.016	−0.016	0.152**	0.144*
	(0.017)	(0.011)	(0.020)	(0.013)	(0.065)	(0.084)
D_{Glass}	−0.002	−0.001	−0.014	−0.018	0.139**	0.287***
	(0.019)	(0.012)	(0.021)	(0.014)	(0.068)	(0.083)
D_{PET}	0.000	−0.002	−0.008	−0.008	0.047	0.030
	(0.008)	(0.008)	(0.009)	(0.011)	(0.030)	(0.048)
$D_{Plastic}$	−0.015***	−0.008	−0.037***	−0.027**	0.085***	0.068
	(0.005)	(0.008)	(0.007)	(0.011)	(0.026)	(0.047)
D_{Other}	0.002	−0.005	−0.007	−0.009	0.049**	0.045
	(0.004)	(0.007)	(0.006)	(0.009)	(0.021)	(0.031)
Year 96	0.044***	0.026***	0.051***	0.032***	0.021	−0.040
	(0.007)	(0.010)	(0.008)	(0.011)	(0.024)	(0.066)
Year 97	0.074***	0.049**	0.085***	0.056**	−0.000	−0.044
	(0.017)	(0.020)	(0.018)	(0.022)	(0.052)	(0.127)
Year 98	0.120***	0.085***	0.143***	0.099***	−0.025	−0.122
	(0.022)	(0.030)	(0.024)	(0.034)	(0.073)	(0.185)
Year 99	0.154***	0.130***	0.183***	0.148***	0.018	−0.177
	(0.026)	(0.037)	(0.029)	(0.042)	(0.088)	(0.239)
Year 00	0.198***	0.171***	0.223***	0.185***	0.109	−0.135
	(0.031)	(0.044)	(0.035)	(0.052)	(0.113)	(0.298)

Table 7 continued

Variables	$\ln w_{total}$		$\ln w_{unsorted}$		$\ln w_{recyclable}$	
	High income	Low income	High income	Low income	High income	Low income
	(1)	(2)	(3)	(4)	(5)	(6)
Year 01	0.239***	0.206***	0.281***	0.224***	0.075	−0.162
	(0.038)	(0.051)	(0.043)	(0.061)	(0.135)	(0.365)
Year 02	0.258***	0.224***	0.307***	0.247***	0.074	−0.275
	(0.044)	(0.058)	(0.051)	(0.070)	(0.162)	(0.432)
Constant	7.208***	5.602***	7.677***	5.348***	−5.400	10.325
	(0.892)	(0.795)	(0.987)	(1.007)	(4.555)	(6.822)
N	2,673	2,630	2,673	2,630	2,671	2,568
Adjusted R^2	0.299	0.273	0.145	0.132	0.411	0.397
Groups	336	329	336	329	336	329

Standard errors are in parentheses and are all corrected for statistics robust to heteroskedasticity and clustered by municipality (of which there were 665)
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 8 Estimation results of fixed-effect model (control variables are omitted): total waste, unsorted waste, and recyclable waste

Variables	$\ln w_{total}$	$\ln w_{unsorted}$	$\ln w_{recyclable}$
$\ln p \times \ln Income$	0.084***	0.065	−0.192
	(0.031)	(0.040)	(0.121)
$\ln p \times y \times \ln Income$	−0.00021	−0.00029*	0.00071
	(0.00014)	(0.00016)	(0.00053)
$\ln p \times y^2 \times \ln Income$	0.0000037	0.0000059	−0.0000291
	(0.0000045)	(0.0000050)	(0.0000200)
$\ln p$	−0.443***	−0.369*	1.037*
	(0.150)	(0.189)	(0.583)
$\ln p \times y$	0.001020	0.001415*	−0.003638
	(0.00068)	(0.000755)	(0.002504)
$\ln p \times y^2$	−0.000015	−0.000027	0.000147
	(0.000021)	(0.000024)	(0.000095)
N	5,303	5,303	5,239
Adjusted R^2	0.274	0.122	0.392
Groups	665	665	665

Standard errors are in parentheses and are all corrected for statistics robust to heteroskedasticity and clustered by municipality (of which there were 665)
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

6 Conclusion

This paper suggests the effect of UBP on waste reduction and recycling lasts a considerable number of years. Our study expands the findings of previous studies in two directions. First, we can estimate the long-run elasticities of total waste, unsorted waste, and recyclable waste.

The estimation results show a monotonically increasing relationship, which implies that long-run elasticity gradually erodes over time, but the size of the effect is very small. The long-run elasticity of recyclable waste is an inverted U-shape, with a turning point 12 years after the introduction of UBP, but the curve is also almost flat. For this reason we conclude that the long-run effect is almost the same as the short-run effect. Second, we examine the long-run effect of UBP between income levels and find differences in income do affect the long-run substitution effect, and that the low-income group responds to UBP by contributing to recycling activity.

Our results have significant policy implications. First of all, the rebound effect is very small and so it can be ignored. Second, the substitution effect is stronger for the low-income group in both the short and long run, so adoption of UBP will be effective for municipalities with a large low-income population. Third, while the high-income group does not care about economic incentives, they voluntarily contribute to recycling efforts wherever a system of recycling is in force. These second and third policy implications suggest that a mix of UBP and recyclable waste collection policies complement each other, since their effects differ between income groups. They suggest that we need a different public relations strategy for different income groups if we wish to promote waste reduction and recycling.

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References

Allers MA, Hoeben C (2010) Effects of unit-based garbage pricing: a differences-in-differences approach. Environ Resour Econ 45:405–428

Amano K, Matsuura A, Yamane T (1999) On the refuse reduction effect of the chargeabilization measure in municipal government. Paper presented at the 10th annual conference of the Japan society of waste management experts. Japan

Asahi Shimbun (2003) Minryoku 2002 CD-ROM. Asahi Shimbun, Tokyo

Bartelings H, Sterner T (1999) Household waste management in a Swedish municipality: determinants of waste disposal, recycling and composting. Environ Resour Econ 13:473–491

Benabou R, Tirole J (2003) Intrinsic and extrinsic motivation. Rev Econ Stud 70:489–520

Besley T, Case A (2000) Unnatural experiments? Estimating the incidence of endogenous policies, recycling and composting. Econ J 110:672–694

Braathen NA (2006) Impacts of unit-based waste collection charges. Working group on waste prevention and recycling, Paris, France

Callan SJ, Thomas JM (1997) The impact of state and local policies on the recycling effort. East Econ J 23:411–423

Callan SJ, Thomas JM (2006) Analyzing demand for disposal and recycling services: a systems approach. East Econ J 32:221–240

Deci EL (1971) Effects of externally mediated rewards on intrinsic motivation. J Pers Soc Psychol 18:105–115

Dijkgraaf E, Gradus R (2004) Cost savings in UBP of household waste—the case of The Netherlands. Resour Energy Econ 26:353–371

Dijkgraaf E, Gradus R (2009) Environmental activism and dynamics of unit-based pricing systems. Resour Energy Econ 31:13–23

Dinda S (2004) Environmental Kuznets curve hypothesis: a survey. Ecol Econ 49:431–455

Ferrara I (2008) Waste generation and recycling. In: OECD (ed) Household behavior and the environment, reviewing the evidence. OECD, Paris
Fullerton D, Kinnaman TC (1996) Household responses to pricing garbage by the bag. Am Econ Rev 86:971–984
Greene WH (2008) Econometric analysis, 6th edn. Pearson Education, Upper Saddle River, NJ
Gruber J, Koszegi B (2001) Is addiction 'rational'? Theory and evidence. Q J Econ 116:1261–1303
Gruber J, Koszegi B (2004) Tax incidence when individuals are time-inconsistent: the case of cigarette excise taxes. J Public Econ 88:1959–1987
Hausman JA (1978) Specification tests in econometrics. Econometrica 46:1251–1271
Hong S (1999) The effects of unit pricing system upon household solid waste management: The Korean experience. J Environ Manage 57:1–10
Hong S, Adams M, Love H (1993) An economic analysis of household recycling of solid wastes: the case of Portland, Oregon. J Environ Econ Manage 25:136–146
Hong S, Adams M (1999) Household responses to price incentives for recycling: some further evidence. Land Econ 75:505–514
Hsiao C (2002) Analysis of panel data, 2nd edn. Cambridge University Press, Cambridge
Huang JC, Halstead JM, Saunders SB (2011) Managing municipal solid waste with unit-based pricing: policy effects and responsiveness to pricing. Land Econ 87:645–660
Japan Waste Management Association (1995–2002) Haikibutsu Shori Jigyo Jittai Chosa Tokei Shiryo (Statistical data on waste disposal operations from 1995 to 2002). Japan
Jenkins RR, Martinez SA, Palmer K, Podolsky MJ (2003) The determinants of household recycling: a material-specific analysis of recycling program features and unit pricing. J Environ Econ Manage 45:294–319
Kinnaman TC (2006) Examining the justification for residential recycling. J Econ Perspect 20:219–232
Kinnaman TC, Fullerton D (1999) The economics of residential solid waste management. NBER Working Paper: 7326
Kinnaman TC, Fullerton D (2000) Garbage and recycling with endogenous local policy. J Urban Econ 48:419–442
Kleibergen F, Paap R (2006) Generalized reduced rank tests using the singular value decomposition. J Econom 48:97–126
Levitt SD, List JA (2009) Field experiments in economics: the past, the present, and the future. Eur Econ Rev 53:1–18
Linderhof V, Kooreman P, Allers M, Wiersma D (2001) Weight-based pricing in the collection of household waste: the Oostzaan case. Resour Energy Econ 23:359–371
Ministry of Environment, Japan (2001) Nihon no Haikibutsu Shori, 1999 (Solid waste management in Japan in 1999). Website: http://www.env.go.jp/recycle/waste_tech/ippan/h11/data/waste_disposal.doc Cited 1 Feb 2012
Ministry of Environment, Japan (2007) Ippan Haikibutsu Yuryoka no Tebiki (A guide to UBP of general waste). Website: http://www.env.go.jp/recycle/waste/tool_gwd3r/ps/ps.pdf. Cited 1 Feb 2012
Ministry of Environment, Japan (2011) Nihon no Haikibutsu Shori, 2009 (Solid waste management in Japan in 2009). Website: http://www.env.go.jp/recycle/waste_tech/ippan/h21/data/disposal.pdf. Cited 1 Feb 2012
Miranda ML, Bynum DZ (1999) Unit based pricing in the United States: a tally of communities. Report submitted to the US Environmental Protection Agency
Nagano City (2007) Kateikei Ippan Haikibutsu Shori no Haishutsu-sha Futan no Arikata ni Tsuite (The concept of householder responsibility for disposal of household waste). Website: http://www.city.nagano.nagano.jp/uploaded/attachment/18932.pdf Cited 1 Feb 2012
Nestor DV, Podolsky MJ (1998) Assessing incentive-based environmental policies for reducing household waste disposal. Contemp Econ Policy 16:401–411
OECD (2006) Impacts of unit-based waste collection charges. In: OECD (ed) Working group on waste prevention and recycling. OECD, Paris
OECD (2008) OECD environmental data COMPENDIUM 2006–2008. Paris
Otsu City (2011) Katei Gomi no Yuryoka ni Tsuite - Toshin (On unit-based pricing of household waste: A report). Website: http://www.city.otsu.shiga.jp/www/contents/1296613869328/activesqr/common/other/4d4a1311002.pdf Cited 1 Feb 2012
Ozdenoren E, Salant SW, Silverman D (2012) Willpower and the optimal control of visceral urges. J Eur Econ Assoc 10:342–368
Podolsky MJ, Spiegel M (1998) Municipal waste disposal: unit pricing and recycling opportunities. Public Works Manage Policy 3:27–39
Rege M (2004) Social norm and private provision of public goods. J Public Econ Theory 6:65–77
Reschovsky JD, Stone SE (1994) Market incentives to encourage household waste recycling: paying for what you throw away. J Policy Anal Manage 13:120–139

Saltzman C, Duggal VG, Williams ML (1993) Income and the recycling effort: a maximization problem. Energy Econ 15:33–38

Staiger D, Stock JH (1997) Instrumental variables regression with weak instruments. Econometrica 65:557–586

Strathman JG, Rufolo AM, Mildner GCS (1995) The demand for solid waste disposal. Land Econ 71:57–64

Suwa T, Usui T (2007) Estimation of garbage reduction and recycling promotion under the containers and packaging recycling law and garbage pricing. Environ Econ Policy Stud 8:239–254

Usui T (2008) Estimating the effect of unit-based pricing in the presence of sample selection bias under Japanese recycling law. Ecol Econ 66:282–288

Van Houtven GL, Morris GE (1999) Household behavior under alternative pay-as-you-throw systems for solid waste disposal. Land Econ 75:515–537

Wertz K (1976) Economic factors influencing households' production of refuse. J Environ Econ Manage 2:263–272

Yamakawa H, Ueta K (2002) Waste reduction through variable charging programs: its sustainability and contributing factors. J Mater Cycles Waste 4:77–86

Yamaya S (2006) Katei Gomi Yuryoka no Genjo to Kadai (Present state of household waste and what needs to be done). Life Environ 51:13–20

Yamaya S (2007) Gomi-Yuryoka (UBP of waste). Maruzen

Yang HL, Innes R (2007) Economic incentives and residential waste management in Taiwan: an empirical investigation. Environ Resour Econ 37:489–519