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Effects of a Unit-Based Pricing Program on Municipal Solid Waste: Evidence from New Taipei City*

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ABSTRACT

This study estimates the effects of the unit-based waste pricing program in New Taipei City. The study used fixed-effects models with district-level panel data regarding waste and recycling from July 2007 to December 2011, and demonstrated that the program was related to a significant 40% reduction in monthly per capita waste and a 15% increase in recycling. City-level data from 2000 to 2017 prove that the waste reduction did not rebound in the long term. Because the results were robust under different model specifications and indicated no adverse effects, the paper provides evidence to support arguments that this type of program can effectively reduce waste in high-population-density municipalities.

Key Words: environmental policy, garbage bag, program evaluation, unit-pricing system, waste management

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I. Introduction

Waste disposal has become a crucial environmental concern. Since the 1990s, unit-based pricing systems, also known as pay-as-you-throw or unit-pricing systems, have been used in the United States and other counties as an incentive for citizens to reduce household waste (Folz and Giles, 2002; Dijkgraaf and Gradus, 2004; Hong, 1999; Usui and Takeuchi, 2014). Compared with the no-fee system, in which waste-management expenditures are funded by taxes, or the flat-fee system, in which citizens pay fixed monthly fees for garbage disposal (Podolsky and Spiegel, 1998; Van Houtven and Morris, 1999), the unit-pricing system charges citizens a garbage disposal fee based on the units (weight or volume) of solid waste that they discard (Folz and Giles, 2002). Therefore, this system provides an incentive to reduce waste to an amount at which the marginal benefit of discarding waste is equal to the marginal cost (i.e., the unit fee, Van Houtven and Morris, 1999). This system can reduce landfill space, incinerator use, and pollution emissions, thereby causing less harm to the environment as a result of reduced waste (Kinnaman, 2006; Tammemagi, 1999).

This study provides useful evidence in an Asian context by evaluating the effectiveness of the garbage bag program in New Taipei City, Taiwan, in reducing waste disposal as well as increasing recycling. We use monthly district-level panel data and use the variation in implementation dates among different districts. By using fixed-effect regression models, we can control for observable and unobservable differences among districts. We also use yearly city-level data to reconfirm the long-term effects. Furthermore, we test whether illegal dumping plays a role in waste reduction and whether nonindustrial water usage increases as an adverse effect of the bag program.

II. Literature Review

Many studies on unit-pricing systems in the late 1990s investigated whether the unit-pricing system reduces solid waste. Nearly all studies have demonstrated that unit-pricing systems reduce solid waste (Dijkgraaf and Gradus, 2004; Folz and Giles, 2002; Fullerton and Kinnaman, 1996; Van Houtven and Morris, 1999; Kinnaman and Fullerton, 2000; Huang et al., 2011). For example, Folz and Giles (2002) analyzed the 1996 municipal data of 2,096 cities in the United States and demonstrated that adopting a unit-pricing policy reduced household waste by 1.16 tons per year. Dijkgraaf and Gradus (2004) indicated that the bag program reduces the weight of solid waste by 51%, which is greater than the reduction in US studies by Fullerton and Kinnaman (1996) (14% weight reduction) and Van Houtven and Morris (1999) (31% weight reduction). By using a difference-in-differences (DID) model and instrumental variables to manage endogeneity problems, Allers and Hoeben (2010) observed a smaller effect (1.66 pounds of unsorted waste reduced per US$1) than those observed in previous literature. Similar to Allers and Hoeben (2010), Kinnaman (2006) indicates that a $1 fee per bag or tag reduces household garbage by 1.92–14.28 pounds per weeks.

Three types of unit-pricing systems have been studied. The first type is the bag/tag program, in which a garbage fee is charged on the basis of the number of units (bags/tags) a household uses. This system requires households to purchase certified garbage bags. Only garbage that has been placed in certified garbage bags may be disposed curbside. The tag program requires certified tags to be attached to garbage containers of certain volumes. The garbage fee is charged according to the number of tags used. The second type is a weight-based system in which households are billed according to the weight of the garbage they discard. The third type is the subscription/can program. People are charged on the basis of the volume of garbage cans they subscribe to, and they can discard up to the volume allowance of the garbage cans. If the garbage produced exceeds the allowance, then citizens must subscribe to a can with a larger volume allowance. Of the three unit-pricing systems, the garbage bag/tag and can subscription programs are common in the United States (Kinnaman, 2006).

Of the three unit-pricing systems, the weight-based system has the largest policy effect of reducing garbage weight and is the most price-elastic system (Dijkgraaf and Gradus, 2004; Allers and Hoeben, 2010; Bel and Gradus, 2016). Moreover, bag programs have a larger effect than can programs do (Van Houtven and Morris, 1999; Dijkgraaf and Gradus, 2004) because under a can program, citizens purchase a maximum monthly allowance. If their waste does not exceed the allowance to which they subscribe, they have a weak incentive to reduce the weight or volume of their waste (Van Houtven and Morris, 1999). Fullerton and Kinnaman (1996) demonstrated that in a bag program, individuals reduced their waste volume by 37%. However, the garbage weight decreased by only 14%, and garbage density increased by 43%. This indicates that because people are likely to compact garbage into fewer bags, the volume-based pricing program has little effect on garbage weight.

Reduced solid waste levels resulting from unit-pricing systems are typically accompanied by an increase in recycled material or the recycling rate (Dijkgraaf and Gradus, 2004; Hong, 1999; Van Houtven and Morris, 1999; Miranda et al., 1994; Usui and Takeuchi, 2014; Dijkgraaf and Gradus, 2017; Starr and Nicolson, 2015). Recycling services are typically free in order to encourage citizens to recycle.

Miranda et al. (1994) demonstrated that recycling programs in cities with unit pricing tend to have higher recycling program participation rates than cities without unit pricing. Studies have indicated a 16%–21% weight increase of recycling with a unit-pricing program (Fullerton and Kinnaman, 1996; Dijkgraaf and Gradus, 2004).

In addition to recycling, people can use several methods to reduce garbage: source reduction (i.e., reducing packaging waste or switching from disposable to reusable goods), composting, illegal disposal, or storage (Erhardt, 2019; Miranda et al., 1994; Dijkgraaf and Gradus, 2004; Kuo and Perrings, 2010; Kuo, 2009). Because of a lack of data, few studies have examined individual behaviors of source reduction, composting, or storage while reducing waste. Dijkgraaf and Gradus (2004) observed that in the Netherlands, compostable waste decreased by more than 60% after adopting a unit-pricing system, indicating that Dutch households use composting methods to reduce compostable waste.

Illegal dumping, which results in an overestimation of the effect on reducing waste, has been mentioned frequently in the literature. Fullerton and Kinnaman (1996) indicated that if calculations account for illegal dumping, the policy effect of waste reduction is likely diluted but still positive. Their results demonstrated that the weight of curbside garbage decreased by 14%, but calculations that accounted for the amount of illegal dumping suggested that the true reduction was only 10%. Their results indicated that illegal dumping may account for 28%–43% of waste reduction. Therefore, illegal dumping should also be analyzed to avoid internal validity concerns. Usui, Chikasada, and Kakamu (2017) confirmed the existence of immoral disposal, which refers to immoral behaviors rather than punishable illegal activity, within Japan's unit-pricing system. However, a later study claimed that the effect size of cross-boundary dumping is relatively small (less than 3%). The closer an area is to the border, the more waste is collected in that area by non-unit-pricing municipalities (Erhardt, 2019).

Although some people argue that recycling wastes a large amount of water (Lahvic n.d.; Tierney, 1996), to our knowledge, no studies on the effect of unit-pricing systems on recycling have analyzed changes in water usage. Our paper is the first to consider this adverse effect of unit-pricing programs.

Data used in the relevant research can be categorized into four basic types: cross-sectional community or municipal data (Folz and Giles, 2002; Dijkgraaf and Gradus, 2004; Kinnaman and Fullerton, 2000), household-level panel data (Fullerton and Kinnaman, 1996; Dijkgraaf and Gradus, 2004; Van Houtven and Morris, 1999), route-level panel data (Van Houtven and Morris, 1999), and municipal panel data (Usui and Takeuchi, 2014; Allers and Hoeben, 2010). Each data type has limitations. First, cross-sectional municipal data are vulnerable to unobservable differences among municipalities that bias the estimates of program effectiveness. People living in unit-pricing system areas might have dumped less solid waste even if programs had not been implemented. Second, the benefit of using household-level panel data is the ability to observe individual behaviors. However, selection bias can occur when response rates are low (Fullerton and Kinnaman, 1996). Because household surveys are conducted by retrospectively asking citizens how much waste they discard, household survey data are constrained by human memory, which can be erroneous (Dijkgraaf and Gradus, 2004; Van Houtven and Morris, 1999; Fullerton and Kinnaman, 1996). Only short-term effects can be estimated because households are typically surveyed for a few weeks before and after policy implementation. Third, route-level data cannot control for socioeconomic characteristics (Van Houtven and Morris, 1999). Therefore, studies using route-level panel data can only control for unobservable differences among routes by using random or fixed-effects models (Dijkgraaf and Gradus, 2004; Van Houtven and Morris, 1999). Fourth, studies using municipal panel data have mainly used fixed effects to control for unobservable characteristics, thereby yielding less biased results (Allers and Hoeben, 2010; Usui and Takeuchi, 2014; Kuo, 2009). However, this type of study may encounter endogeneity problems. For example, cities with large amounts of waste are likely to implement unit-pricing programs to incentivize waste reduction. Studies may use instrumental variables to manage endogeneity (Allers and Hoeben, 2010).

Most research has studied unit-pricing programs in the United States or Western countries (Lakhan, 2015; Fullerton and Kinnaman, 1996; Miranda et al., 1994; Van Houtven and Morris, 1999; Dijkgraaf and Gradus, 2004; Allers and Hoeben, 2010; Folz and Giles, 2002; Huang et al., 2011; Van Beukering et al., 2009; Bucciol et al., 2015), whereas little research has been conducted in Asian settings. Because the composition of solid waste differs with lifestyle and culture, these are likely to influence program effectiveness. Hong (1999) surveyed 160 households in 20 Korean cities that charge different unit prices. The results indicated that waste in most (19 out of 20) cities was reduced considerably (from 8% to 57.4%). Even fewer studies have evaluated long-term effects over more than five years (Allers and Hoeben, 2010; Usui and Takeuchi, 2014; Dijkgraaf and Gradus, 2009). Usui and Takeuchi (2014) examined the long-term effect on waste generation and recycling by using panel data of 665 Japanese cities and observed a small rebound effect, whereas Dijkgraaf and Gradus (2009) observed no evidence of an awareness erosion effect.

Some research on the effect of the unit-pricing system in Taipei City is related to our research. Tsai and Sheu (2009) used a DID approach to compare outcomes before and after implementing the program in Taipei and other areas of Taiwan to analyze the effect of unit pricing on waste and recycling. They observed that waste in Taipei decreased by 22%. However, the authors claimed that 60% of the reduced waste resulted from the increased waste dumping in neighboring New Taipei City. They also did not observe a significant increase in the recycling rate because of the existing national recycling program. Kuo and Perrings (2010) and Kuo (2009) studied the effects of mixed instruments by using panel data of 18 cities in Taiwan and Japan. Kuo and Perrings (2010) confirmed that the unit-pricing and mandatory recycling programs both reduced waste disposal and increased recycling, and no illegal dumping was observed. Kuo (2009) demonstrated that using transparent garbage bags increased paper recycling, decreased non-recyclable waste disposal, and could be a cost-effective means of supporting mandatory recycling because of the reduced inspection costs.

In contrast to research that has studied the case of Taiwan by using yearly city-level data (Kuo and Perrings, 2010; Kuo, 2009; Tsai and Sheu, 2009), our research uses monthly district-level panel data. Although city-level data analysis provides results that apply to a larger geographical area and more people, district-level data analysis is advantageous and can provide additional information in the field. (Lindo, 2015). First, using a disaggregated unit of analysis, such as districts rather than cities, can mitigate biases because districts are more homogenous in demographic characteristics within a city. Therefore, districts in the same city comprise a more suitable comparison group (Phillips and Land, 2012). Second, disaggregated data (i.e., monthly and district data) can increase the number of observations, thus increasing statistical power (Phillips and Land, 2012; Lindo, 2015). To acknowledge the pros and cons of using aggregate versus disaggregate data, we also use yearly city-level data to confirm the district-level results and examine the long-term effect over approximately 10 years.

In summary, the literature so far has demonstrated that unit-pricing systems significantly reduce household waste. However, the household garbage reduction rate differs by country. Dijkgraaf and Gradus (2004) implied that the bag program works slightly better in the Netherlands than in the United States (Fullerton and Kinnaman, 1996; Van Houtven and Morris, 1999). In Korea, Hong (1999) yielded diverse results from 20 cities. Household garbage in one city even increased after implementing the bag program. The policy effect is heterogeneous in different contexts. Moreover, previous studies did not compare the effect difference between the implementation stage without penalty and the stage with penalty. The effect of implementing a policy only is likely weaker than that of implementing a policy with violation penalties. In addition, studies have not examined the lag effects of these policies, and few studies have considered possible rebound effects in the long term (Usui and Takeuchi, 2014). A policy may be effective at first but become less effective over time. Fourth, although numerous studies have accounted for illegal dumping or other adverse effects (such as administrative costs) (Dijkgraaf and Gradus, 2017; Allers and Hoeben, 2010; Miranda et al., 1994; Fullerton and Kinnaman, 1996), none have assessed whether increased recycling increased water waste.

Here, we use administrative panel data from New Taipei City to avoid the aforementioned data limitations. Because all districts in New Taipei City adopted the bag program at different times after 2011, we were able to use the variations in implementation dates of the panel data while avoiding the concern that some districts adopted the program for endogenous reasons. We also use city-level data as a robustness check to confirm the long-term effects. Moreover, in contrast to research that has estimated either the implementation or enforcement effects (Kuo, 2009; Tsai and Sheu, 2009), program stages (notification, implementation, and enforcement) are differentiated in this study to understand whether the policy effects differ in different policy intervention stages. We also investigated the illegal dumping concern, considered the autocorrelation problem of the panel data in a long panel, examined water usage, and assessed waste patterns in the long term to ensure result accuracy.

III. Garbage Bag Program in New Taipei City

In most areas of Taiwan, garbage fees are charged along with water fees. Citizens pay water fees, part of which are used for garbage disposal, to Taiwan Water Corporation (Taiwan Water Corporation, 2013). Charging water and garbage fees together saves administrative costs for municipal governments. However, because the garbage fee is not linked to the amount of garbage that users discard, it provides no incentives to reduce waste.

To reduce garbage and implement the “user pays” principle, Taipei City adopted its garbage bag program in 2000. In 2008, New Taipei City also adopted the policy. This study evaluates the policy effects of the garbage bag program in New Taipei City. New Taipei City has a total of 29 districts. As Table 1 indicates, these districts implemented the policy sequentially. The program was first implemented in Shenkeng District in July 2008 and then implemented by the remaining districts gradually. The last nine districts implemented the policy in December 2010 (Environmental Protection Bureau, New Taipei City Government, 2013).

This program was phased in in three stages: notification, implementation, and enforcement. In the notification (advertising) stage, households were encouraged to use the garbage bags without penalty. District offices used several methods to introduce the program to New Taipei City citizens, such as distributing fliers or providing briefings. Citizens may have even received incentives such as lottery

Table 1: Program Stage Implementation Dates of the 29 Districts of New Taipei City

<table>
<tr><th>District</th><th>Notification Date</th><th>Implementation Date</th><th>Enforcement Date</th></tr>
<tr><td>Shenkeng</td><td>2008 May 20th</td><td>2008 Jul. 1st</td><td>2008 Aug. 1st</td></tr>
<tr><td>Bali, Shiding, Yingge</td><td>2009 Mar. 20th</td><td>2009 May 1st</td><td>2009 Jun. 1st</td></tr>
<tr><td>Yonghe</td><td>2009 Apr. 30th</td><td colspan="2">2009 Jul. 1st</td></tr>
<tr><td>Tucheng</td><td>2009 Apr. 30th</td><td>2009 Jul. 1st</td><td>2009 Aug. 1st</td></tr>
<tr><td>Sanzhi</td><td>2010 Mar. 26th</td><td>2010 May 1st</td><td>2010 Jun. 1st</td></tr>
<tr><td>Zhonghe</td><td>2009 Oct. 1st</td><td colspan="2">2010 Jul. 1st</td></tr>
<tr><td>Shulin</td><td>2010 Mar. 14th</td><td rowspan="7">2010 Jul. 1st</td><td rowspan="7">2010 Aug. 1st</td></tr>
<tr><td>Taishan</td><td>2010 Apr. 7th</td></tr>
<tr><td>Tamsui</td><td>2010 Apr. 27th</td></tr>
<tr><td>Sanxia</td><td>2010 May 2nd</td></tr>
<tr><td>Sanchong</td><td>2010 May 17th</td></tr>
<tr><td>Pinglin</td><td>2010 May 31st</td></tr>
<tr><td>Linkou, Jinshan</td><td>2010 Jun. 1st</td></tr>
<tr><td>Shimen</td><td>2010 Jun. 1st</td><td>2010 Aug. 1st</td><td>2010 Sep. 1st</td></tr>
<tr><td>Pingxi</td><td>2010 Jul. 13th</td><td rowspan="3">2010 Nov. 1st</td><td rowspan="3">2010 Dec. 1st</td></tr>
<tr><td>Banqiao</td><td>2010 Aug. 2nd</td></tr>
<tr><td>Xinzhuang</td><td>2010 Aug. 28th</td></tr>
<tr><td>Gongliao</td><td>2010 Aug. 12th</td><td rowspan="9">2010 Dec. 1st</td><td rowspan="9">2011 Jan. 1st</td></tr>
<tr><td>Xindian</td><td>2010 Aug. 13th</td></tr>
<tr><td>Wugu</td><td>2010 Aug. 16th</td></tr>
<tr><td>Shuangxi</td><td>2010 Aug. 17th</td></tr>
<tr><td>Wulai</td><td>2010 Aug. 18th</td></tr>
<tr><td>Luzhou</td><td>2010 Aug. 21st</td></tr>
<tr><td>Wanli</td><td>2010 Aug. 29th</td></tr>
<tr><td>Xizhi</td><td>2010 Sep. 8th</td></tr>
<tr><td>Ruifang</td><td>2010 Sep. 16th</td></tr>
</table>

Note. Refer to New Taipei City Garbage Bag Policy Forum: http://60.251.138.68/2008gtrash/index.php for crucial dates of the program. (Accessed April 24, 2012).

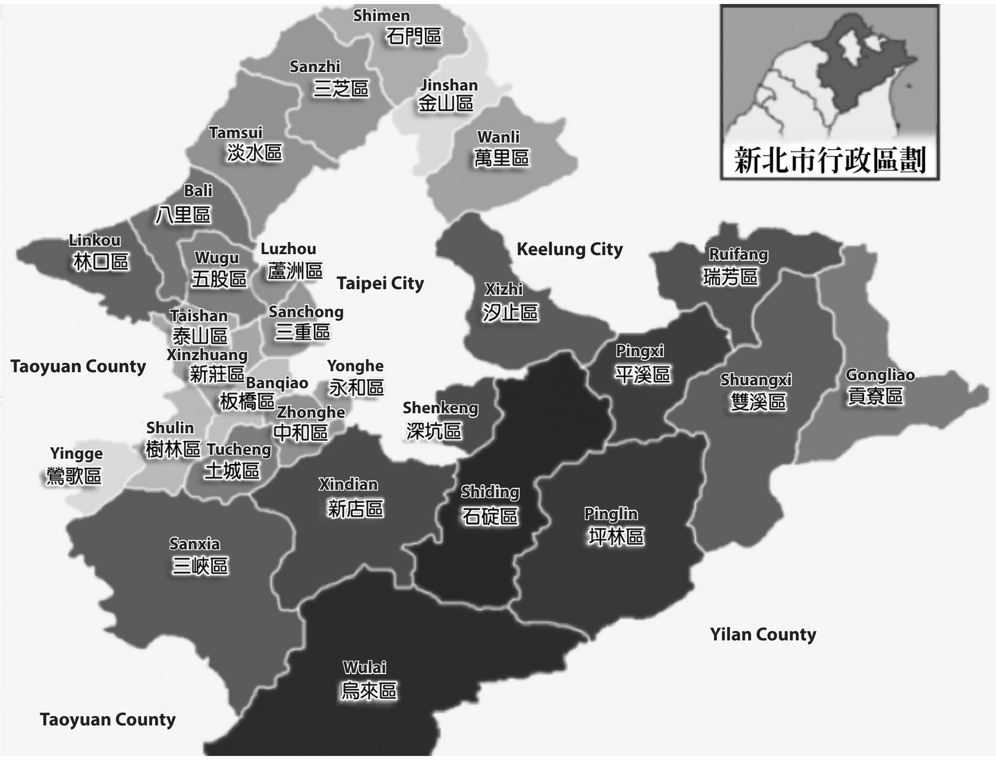

Fig. 1: Map of New Taipei City

Note. Figure Accessed on March 26, 2013 from Wikipedia: http://en.wikipedia.org/wiki/New_Taipei_City

tickets for using the bags. In the implementation stage, people were required to use the garbage bags, otherwise city workers could refuse to collect their waste. During the enforcement stage, citizens who discarded waste without using the official bags were fined NT$1200–$6000 (US$40–$200) (Environmental Protection Administration, Taiwan, 2017c; Liberty Times Net, 2009). The enactment dates of the three stages are presented in Table 1. Because other cities in Taiwan are considering adopting the unit-pricing program (Yang, 2016), our study provides empirical evidence for decision makers in these cities.

IV. Data

This study uses monthly panel data of all 29 districts in New Taipei City; data were downloaded from the New Taipei City Garbage Bag Policy Forum (Environmental Protection Bureau, New Taipei City Government, 2013). The data span 66 months from July 2007 to December 2012 and include the one year before the first district implemented the program and the two years after the last districts implemented the program. The data contain a total of 1,914 district-months.

The dependent variable is the monthly average solid waste per capita in each district. The waste was measured by weight (kg) and collected by curbside garbage trucks every day. The waste included household garbage as well as waste from schools, government agencies, and organizations, but did not include bulk waste, kitchen waste, recycling, or industrial waste. The Garbage Bag Policy Forum also provides dates of notification, implementation, and enforcement for each district. Hence, we can investigate the effect of the unit-pricing system in each stage of the policy.

Studies have suggested that demographic characteristics are correlated with household garbage amounts (Fullerton and Kinnaman, 1996; Hong, 1999; Van Houtven and Morris, 1999; Folz and Giles, 2002; Dijkgraaf and Gradus, 2004). We collected district-level monthly demographics, including population density, gender ratio, age group distribution, the indigenous population percentage, the percentage of people who moved in or out of the district, birth and death rates, and monthly marriage and divorce percentages from the New Taipei City Government Bureau of Civil Affairs (Department of Civil Affairs, New Taipei City Government, 2017). Population density, gender, and age are related to lifestyle, whereas birth, death, and marriage are events that may change daily waste production. Summary statistics are presented in Table 2.

Typically, unit-pricing programs are introduced concomitantly with curbside recycling programs (Van Houtven and Morris, 1999), which may confound the effects of unit-pricing programs by shifting solid waste to recyclables. However, when the garbage bag program was implemented in New Taipei City, a waste-sorting program that requires citizens to sort recycling from waste had been implemented throughout the country since 2006 (Environmental Protection Department, New Taipei City Government, 2017). Thus, the disturbance effect of a recycling program is not a concern in this study. By contrast, the garbage bag program may increase recycling amounts because citizens have an incentive to reduce garbage waste by increasing recycling. Therefore, we evaluate whether the garbage bag program increased recycling. Here, recycling includes kitchen waste and household, school, or other organizational recycling but does not include bulk recycling. Recycling data were also collected from the New Taipei City Garbage Bag Policy Forum.

We collected waste data at the city level from the website of National Statistics, Taiwan (Directorate-General of Budget, Accounting and Statistics, Taiwan, 2018). To study long-term trends, we collected yearly waste data from 2000 to 2017 of nearby cities (Taipei, Keelung, and Taoyuan) for comparison with those of New

Taipei City. The data include average daily waste (measured tons) and per capita daily waste (measured in kilograms). Unfortunately, monthly data for these nearby cities are unavailable.

Table 2: Descriptive Statistics

Variable	Mean	S. D.	Min	Max	Description
			Dependent Variable		
Waste	12.52	4.84	1.81	27.70	Monthly solid waste per capita (kg/person)
Recycling	11.28	4.64	1.04	47.04	Monthly recycling per capita (kg/person)
			District-Month Level Control Variable		
Density	6.66	10.55	0.0166	41.548	District Density (1,000 people/km^2)
(Population)	133.45	147.98	5.11	557.44	Population (1,000 people)
(Area)	70.78	68.13	5.71	321.13	District area (km^2)
Age 0–14	14.99%	0.0316	0.0086	0.2349	% of children aged 0–14 (base)
Age 15–64	73.73%	0.0437	0.3790	0.7952	% of adults aged 15–64
Age 65	11.29%	0.0661	0.0476	0.6124	% of elderly adults aged over 65
Male	48.98%	0.0202	0.4376	0.5216	% of males
Female	51.02%	0.0202	0.4784	0.5624	% of females (base)
Native population	2.74%	0.0799	0.0012	0.4520	% of aboriginal inhabitants
Birth rate	0.07%	0.0002	0	0.0021	Birth rate
Death rate	0.05%	0.0003	0	0.0027	Death rate
Move-in rate	0.47%	0.0018	0.0009	0.0176	% of people moved in
Move-out rate	0.42%	0.0013	0.0007	0.0203	% of people moved out
Marrying rate	1.00%	0.0005	0	0.0028	% of people who got married in the month
Divorcing rate	0.04%	0.0002	0	0.0018	% of people who got divorced in the month
N	1,914				
			City-Year Level Control Variable		
Income	273.86	8.72	262.34	285.06	Annual per capita disposable income (1,000 NTD)
Percent married	50.78	0.59	50.05	51.55	% of married citizens aged 15 and above
Unemployment	4.60	0.79	3.80	5.90	% of unemployment in the labor market
N	6				

Note. The analysis period is from July 2007 to December 2012. Because the recycling data had one missing value, the number of observations for recycling was 1,913.

V. Identification Strategy

We expect that the garbage bag program offers an incentive to save money by reducing waste and partly converting waste into recyclables. We also expect that the strict policy instrument in the enforcement stage, which includes punishment, is more effective than the weaker instrument in the notification and implementation stages. Because the garbage bag program was implemented in districts at different times, we can identify program effects by using a fixed-effects model. The main regression equation is expressed as follows:

$$Y_{it}=\alpha_{nt}P_{nt}+\alpha_{im}P_{im}+\alpha_{ef}P_{ef}+\beta X_{it}+\delta_y+\delta_m+\gamma_i+\varepsilon_{it}. \quad (1)$$

Y_{it} is the outcome of interest representing the average waste per capita in each district i and time t (66 months in total). We also use the amount of materials recycled as the dependent variable to estimate the increase in recycling converted from reduced waste due to the program intervention. P indicates the three stages of the garbage bag program: P_{nt} is a dummy variable equal to 1 after program notification, P_{im} equals 1 after program implementation, and P_{ef} equals 1 after program enforcement. By using this equation structure, the effect of the garbage bag program in the implementation stage is $\alpha_{nt}+\alpha_{im}$, and that at the enforcement stage is $\alpha_{nt}+\alpha_{im}+\alpha_{ef}$. Although our model assumes a constant effect after program enforcement, Usui and Takeuchi (2014) suggested a rebound effect of unit-based pricing in the long term. However, in Figures 2-1, 2-2, and 2-3, we do not observe such rebound effects. The flat trends in the pretreatment period also suggest that the program does not have the endogeneity concern that waste was reduced before program implementation.

X_{it} is a vector of covariates representing district-level characteristics that may affect the amount of waste and material recycled over time. We use district fixed effects γ_i to control for time-invariant characteristics and time fixed effects δ_y and δ_m to control for yearly and monthly trends common among districts. District fixed effects are critical when some district-level control variables, such as wealth and attitudes toward environmental protection, are unavailable. Wealth levels may be correlated with consumption, thereby affecting waste and recycling and more crucially, the response to financial incentives established by the garbage bag program. Comparative wealth levels among districts are unlikely to vary within our study period. This type of time-invariant unobserved heterogeneity can be canceled out by differentiating the outcome changes in districts before and after program intervention, thereby controlling for unobserved district characteristics (Khandker et al., 2009).

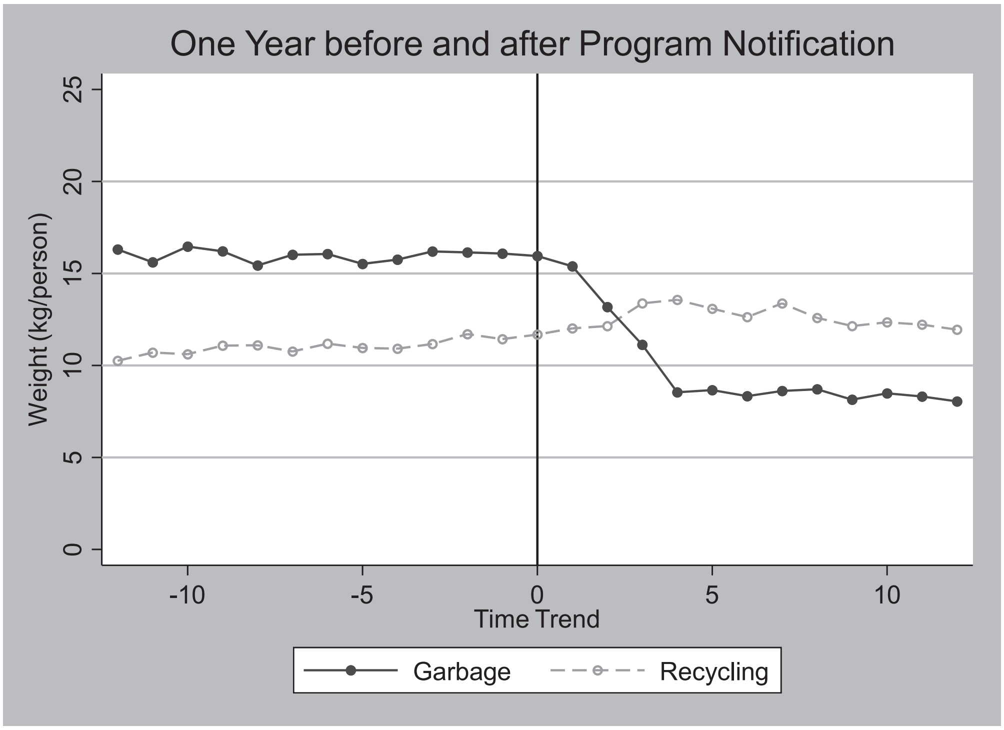

Fig. 2-1: Time Trends of Monthly Per Capita Waste and Recycling among 29 Districts before and after Program Notification

Note. T=0 represents the month in which the program was advertised in districts. Negative time numbers represent months before program notification. Positive time numbers represent months after program notification.

We use time fixed effects to control for possible time patterns or “historical” events that are constant across districts but vary over time. For example, people’s expenditures fluctuate over time with the economic cycle, or because of growing environmental awareness, people tend to recycle more and produce less waste over time. A plastic bag restriction policy was implemented in 2002 and a waste sorting program was implemented in 2006 (Environmental Protection Administration, Taiwan, 2017a; 2017b); since 2002, recycling has increased each year (Environmental Protection Administration, Taiwan, 2018b). The time fixed effects may help reduce this internal validity concern. The year fixed effects δ_y are set for longer time trends, and month (January to December) fixed effects δ_m control for seasonal fluctuations.

Although including district fixed effects can eliminate possible endogeneity bias due to time-invariant unobserved factors, the timing of policy adoption may have been related to trends of dependent variables in the pre-policy period. If this is the case, we may observe a reduction in waste and an increase in recycling before

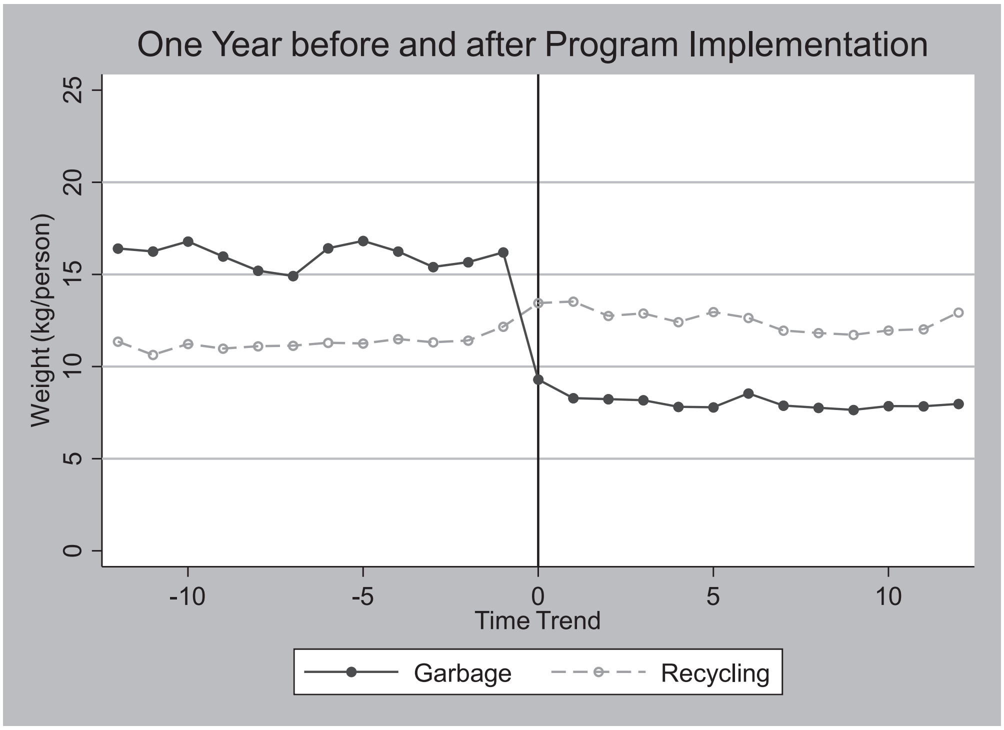

Fig. 2-2: Time Trends of Monthly Per Capita Waste and Recycling among 29 Districts before and after Program Implementation

Note. T=0 represents the month in which the program was implemented in districts. Negative time numbers represent months before program implementation. Positive time numbers represent months after program implementation.

policy adoption in each district. Therefore, we align the policy adoption time across districts[1] shown in Figures 2-1, 2-2, and 2-3. Both waste and recycling trends are approximately horizontal and parallel to each other. Therefore, we conclude the trends of dependent variables in districts are not correlated with the timing of policy adoption. A more sophisticated means of evaluating this problem is the so-called "event study" such as that used by Goodman-Bacon (2018, Figure 5). However, because the trends shown in our figures are sufficiently clear, we refrained from introducing more complexity.

1 Although the data presented in Figure 2 are aggregated trends for all of New Taipei City, an upward or downward trend in policy adoption time would emerge if the trends were correlated with the timing of policy adoption because we align the policy adoption time across districts.

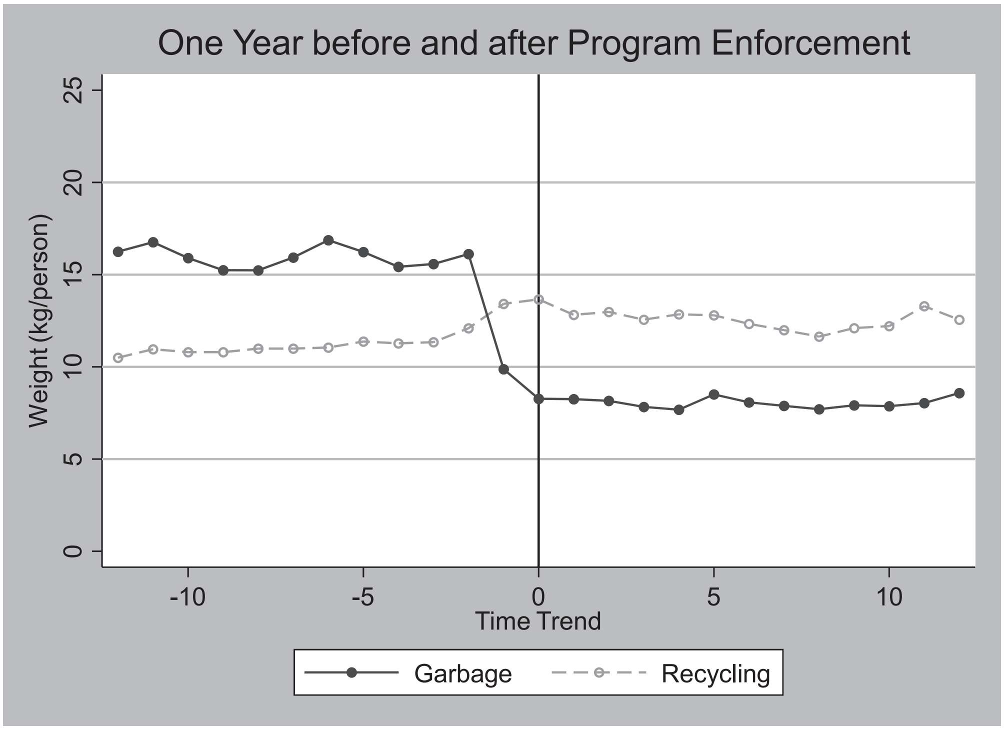

Fig. 2-3: Time Trends of Monthly Per Capita Garbage and Recycling among 29 Districts before and after Program Enforcement

Note. T=0 represents the month in which the program was enforced in districts. Negative time numbers represent months before program enforcement. Positive time numbers represent months after program enforcement.

VI. Results

A. Waste Time Trends

Figure 2 displays the change in average monthly per capita waste and recycling of the 29 districts, ranging from 12 months before (negative labels on the *x*-axis) to 12 months after (positive labels on the *x*-axis) implementing program instruments. Figure 2-1 presents the time trends of garbage waste and recycling amounts before and after program notification. Figures 2-2 and 2-3 display those before and after program implementation and enforcement, respectively.

As the graphs demonstrate, the waste and recycling weights did not differ considerably immediately after the notification stage. Program notification alone yielded the weakest program effect. The program has the most significant effect in the implementation stage, when citizens were refused garbage service unless they used official garbage bags. Waste was reduced by approximately half the original amount after program implementation, and some reduction waste contributed to the slightly increased recycling amounts. Recycling increased significantly immediately after program implementation. During the enforcement stage when citizens faced a penalty for not using official bags, they discarded the least waste, suggesting that stricter program instruments are effective. However, the effects on waste or recycling do not appear to differ considerably between program implementation and enforcement stages.

Figure 3 illustrates the long-term trends of monthly waste at the city level. Figure 3-1 displays the long-term monthly waste trends in New Taipei City and nearby cities (Taipei City, Keelung, and Taoyuan), whereas Figure 3-2 displays the long-term trends of per capita monthly waste in those cities. Both figures indicate a decreasing trend in waste over time in all cities. However, New Taipei City had the most significant decrease when implementing the unit-pricing bag program, particularly in 2011, when all districts in New Taipei City were participating in this program. Both figures illustrate that New Taipei City had the largest amount of monthly waste per capita before 2008, and the amount of waste decreased rapidly

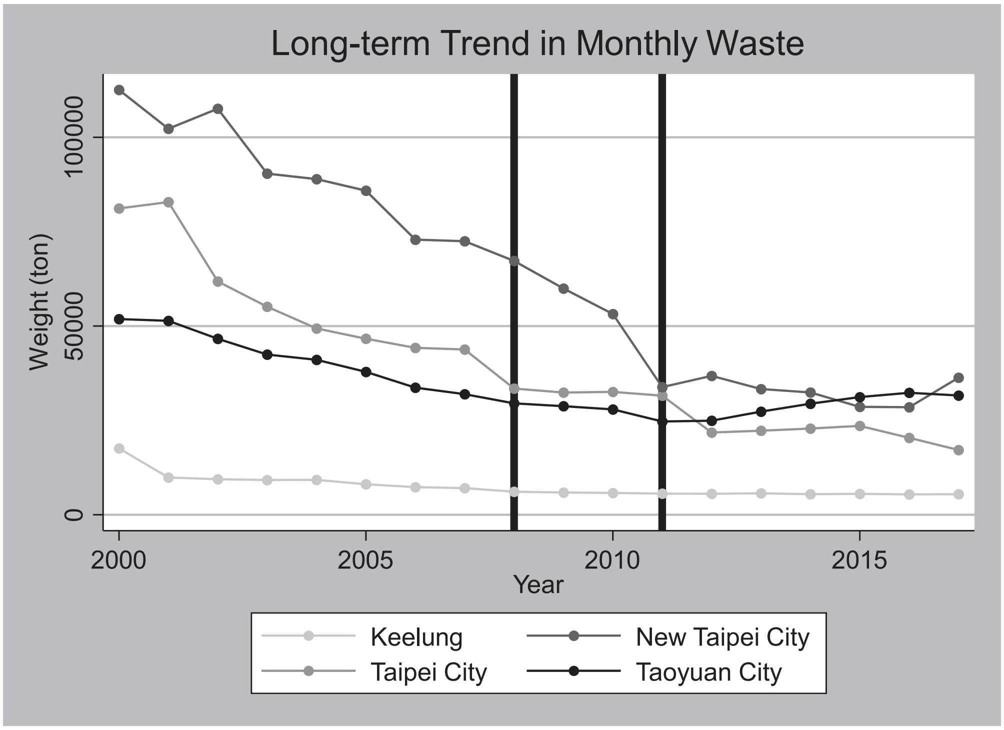

Fig. 3-1: Long-term Monthly Municipal Waste Trends

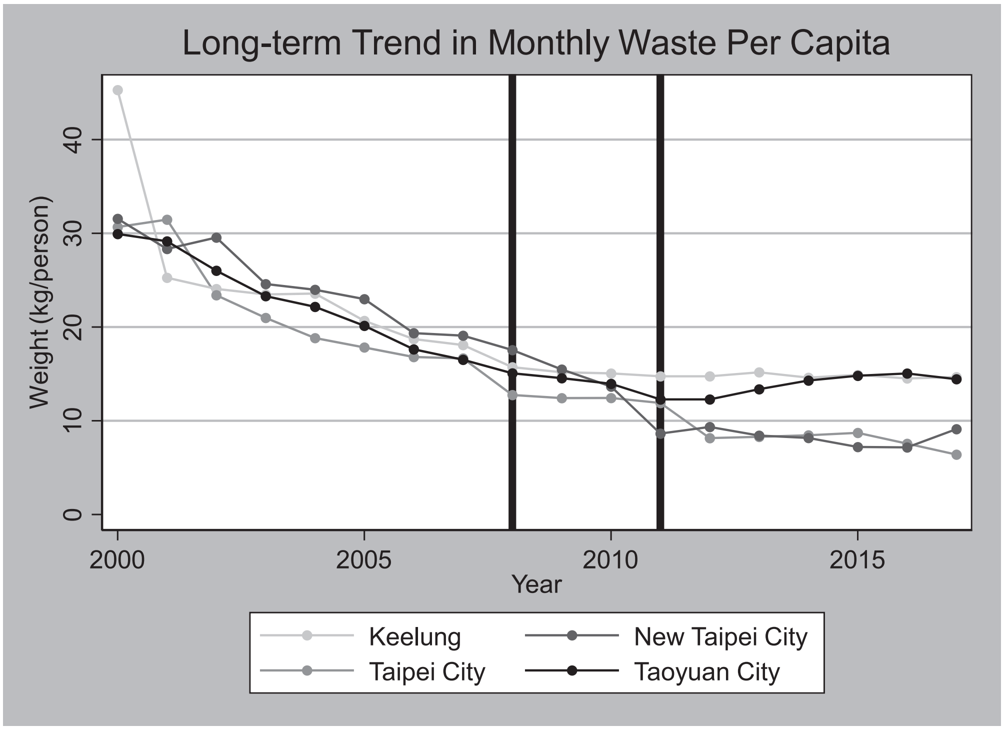

Fig. 3-2: Long-term Per Capita Monthly Municipal Waste Trends

and approached that in other cities after 2011. The figures also indicate no increase in waste in nearby cities (implying no illegal dumping) and no significant rebound effect of the program on waste in the long term.

B. Program Effects on Waste and Recycling

Table 2 presents descriptive statistics of the dependent variables (municipal waste and recycling) and control variables of New Taipei City districts from 2008 to 2012. With an average population density of 6,700 people/km^2, the average New Taipei City resident discarded approximately 12.52 kg of solid waste per month in addition to 11.28 kg of recycling. In addition, 74% of citizens were aged 15-64 years, and 15% were aged 0-14 years. Women were more numerous than men (51%:49%), and only 3% of citizens were indigenous. Each month, 0.07% of the population was born, and 0.05% of the population passed away; 0.47% of the population moved into New Taipei City, and 0.42% moved out; 1% of citizens registered marriages, and 0.04% registered divorces. In addition to the district-month-level control variables, we include several crucial city-year-level control variables that are unavailable at the district-month level, including per capita income, percentage married, and unemployment rate. Including these year-level variables prevents omitted variable bias for the model estimates without fixed effects.

Table 3 presents the effects of the unit-pricing bag program on waste and recycling. The top panel displays the effects on per capita solid waste, and columns 1-4 display different model specifications. Column 1 is a simple ordinary least squares

Table 3: Estimated Effects of Garbage Bag Program on Waste and Recycling Weight

Program Stages	Pretreatment Mean	1	2	3	4
Monthly Waste (kg/per person)					
Notification	16.73	−0.446	−0.860**	−0.204	−0.229
		(0.221)	(0.241)	(0.216)	(0.268)
Implementation	16.78	−6.764***	−6.527***	−6.626***	−6.849***
		(0.371)	(0.438)	(0.377)	(0.347)
Enforcement	16.80	−1.139***	−1.262**	−0.832	−0.666
		(0.408)	(0.454)	(0.434)	(0.434)
Adj. R^2		0.730	0.791	0.855	0.864
N			1,914		
Monthly Recycling (kg/per person)					
Notification	8.06	2.387***	0.890	0.318	0.594
		(0.562)	(0.484)	(0.349)	(0.388)
Implementation	8.26	1.062	1.489*	1.106**	1.575***
		(0.761)	(0.692)	(0.374)	(0.354)
Enforcement	8.39	−0.424	0.020	0.954	0.630
		(0.536)	(0.521)	(0.654)	(0.614)
Adj. R^2		0.102	0.431	0.347	0.354
N			1,913		
Control variables			✓	✓	✓
District FE				✓	✓
Year FE				✓	
Month dummies				✓	
Time dummies					✓

Note. Robust standard errors in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$. The recycling data had a missing value. The pretreatment means in the second column represent the means of dependent variables in the pretreatment periods, which were before all districts implemented the policy instruments. Time dummies consist of 66 month dummies covering the entire study period.

model without control variables or fixed effects. Column 2 presents estimates with control variables, and column 3 presents the main regression that adds district fixed effects and year and month dummy variables. Column 4 replaces the year and month dummies with 66 monthly time dummies to control for the time trend. The means of the dependent variables in the pretreatment period are presented in the second column. We also differentiate the effects among the three policy instrument stages: notification, implementation, and enforcement.

Table 3 indicates that implementing the garbage-bag program was associated with a decrease in monthly per capita solid waste by approximately 6.6–6.8 kg across model specifications, which is approximately 40% of the pretreatment mean. This significant waste reduction is consistent with the observations in Figure 2.

The garbage bag program was associated with an increase in monthly per capita recycling by approximately 1.1–1.6 kg, as shown in the bottom panel of Table 3. This increase in recycling was approximately 13%–19% of the pretreatment mean. This may indicate that some of the reduced waste was transferred to recycling. However, the magnitude of the increased recycling is not as large as that of the reduction in waste.

Table 4 reports district characteristics associated with the amount of solid waste. The table demonstrates that districts with more marriages per month discarded more waste. This may occur because people produce a large amount waste during weddings. In addition, when including district and time fixed effects (Column 3), citizens living in high-density areas and in districts where more people moved out per month appeared to live in an eco-friendly way and appeared to discard less waste. However, none of the district characteristics were associated with recycling when controlling for fixed effects.

Table 4: Control Variable Estimates

	Dependent Variable			
	Garbage		Recycling	
	With Control Variables	With Control Variables & FE	With Control Variables	With Control Variables & FE
Program Stages				
Notification	−0.860**	−0.204	0.890	0.318
	(0.241)	(0.216)	(0.484)	(0.349)
Implementation	−6.527***	−6.626***	1.489*	1.106**
	(0.438)	(0.377)	(0.692)	(0.374)
Enforcement	−1.262**	−0.832	0.020	0.954
	(0.454)	(0.434)	(0.521)	(0.654)

Table 4: Control Variable Estimates (continued)

	Dependent Variable			
	Garbage		Recycling	
	With Control Variables	With Control Variables & FE	With Control Variables	With Control Variables & FE
Control Variables				
Density (1000 ppl/km^2)	−0.025	−2.758***	−0.060	2.176
	(0.024)	(0.689)	(0.052)	(1.844)
Age 15-64 (%)	0.416**	−0.503	0.052	0.263
	(0.143)	(0.317)	(0.238)	(0.521)
Age over 65 (%)	0.312**	−0.378	−0.038	0.102
	(0.097)	(0.251)	(0.197)	(0.416)
Male (%)	0.565***	−1.292	0.894*	2.519
	(0.119)	(0.714)	(0.385)	(1.676)
Aborigines (%)	0.065***	1.650	0.146***	−0.311
	(0.005)	(0.865)	(0.018)	(1.751)
Birth rate (%)	−11.83**	−1.911	−11.200	1.240
	(3.313)	(2.059)	(8.010)	(5.108)
Death rate (%)	0.606	0.537	−19.61*	−0.583
	(4.501)	(2.070)	(8.901)	(1.961)
Move-in (%)	0.538	−0.575	−2.759	−0.656
	(0.784)	(0.428)	(2.001)	(0.516)
Move-out (%)	0.550	−1.322**	0.648	0.516
	(0.686)	(0.425)	(1.281)	(0.634)
Get married (%)	4.473*	7.082***	−0.373	−4.048
	(1.653)	(1.315)	(4.368)	(3.218)
Get divorced (%)	4.905	0.526	−1.489	−2.467
	(3.485)	(1.386)	(5.391)	(3.805)
City Level Control Variables				
Marriage rate	0.600*		−0.610	
	(0.274)		(0.660)	
Per capita income	−0.015		0.017	
	(0.017)		(0.017)	
Unemployment rate	−0.202		1.187***	
	(0.256)		(0.250)	
Adjust R-square	0.791	0.855	0.431	0.347
N	1,914		1,913	

Note. Robust standard errors in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$. The recycling data had one missing value. Columns with control variables correspond to column 2 in Table 3. Columns with control variables and fixed effects (FE) correspond to column 3 in Table 3.

C. Illegal Dumping

Apart from conversion to recycling and source reduction, waste could also be reduced by being illegally dumped in surrounding areas where the program is not implemented. Illegal dumping would undermine the effectiveness of the bag program.

To understand whether illegal dumping occurred, we add the dummy variable N_{it} to regression equation (1). In regression equation (2), P_{it} represents the implementation of the unit-pricing bag program in a district (1 if the district implemented the program). Notification and enforcement stages are omitted here because the aforementioned results suggest their insignificance in waste reduction. N_{it} indicates whether any districts near district i had implemented the bag program (1 if any nearby districts implemented the program). We expect the coefficient of the interaction term $N_{it} \times P_{it}$ to be positive if illegal dumping occurred.

$$Y_{it} = \alpha_1 P_{it} + \alpha_2 N_{it} + \alpha_3 (N_{it} \times P_{it}) + \beta X_{it} + \delta_y + \delta_m + \gamma_i + \varepsilon_{it} \tag{2}$$

The partial effect of program implementation in nearby districts on the municipal waste of district i is expressed as equation (3). The logic is that the nearby districts contribute differently to the waste of a district i if the district i has also implemented the program. In other words, we hypothesize that citizens would not illegally discard their waste across the border if the nearby district has also implemented the bag program. Otherwise, nearby districts are more likely to divert their waste to a district that has not implemented the unit-pricing program.

$$\frac{\Delta Y_{it}}{\Delta N_{it}} = \alpha_2 + \alpha_3 P_{it} \tag{3}$$

The results in Table 5 do not provide sufficient evidence of illegal dumping. The illegal dumping variable (N_{it}) is statistically insignificant and has a downward pattern, suggesting that implementing the bag program in nearby districts did not significantly increase waste (or recycling) in a district that did not implement the program (when $P_{it} = 0$). The positive coefficient of the interaction term between the illegal dumping variable and the program implementation variable ($N_{it} \times P_{it}$) suggests that when a district and its nearby districts implemented the bag program, the amount of waste would rebound in the district. However, this coefficient is only weakly significant.

Cross-boundary shipping out of New Taipei City may have occurred. If this occurred, the waste in nearby cities or counties, particularly those sharing borders with New Taipei City, would have increased after program implementation. How-

Table 5: Program Effect with Illegal Dumping

Dependent Variables	Pretreatment Mean	(1) Without Control Variables & FE	(2) With Control Variables	(3) With Control Variables & FE
Monthly Waste (kg/pp)				
Implementation	16.78	−8.045***	−8.469***	−8.002***
		(0.544)	(0.494)	(0.514)
Nearby Implementation		−0.535	−1.060**	−0.579
		(0.394)	(0.373)	(0.356)
Implementation ×		0.155	0.513	0.898*
Nearby Implementation		(0.529)	(0.469)	(0.433)
Adj. R^2		0.731	0.792	0.855
N		1,914		
Monthly Recycling (kg/pp)				
Implementation	8.26	5.155***	3.064***	2.904*
		(0.908)	(0.855)	(0.855)
Nearby Implementation		2.220*	0.629	−0.161
		(0.909)	(0.593)	(0.431)
Implementation ×		−4.206***	−1.483	−1.236
Nearby Implementation		(1.099)	(0.986)	(0.725)
Adj. R^2		0.118	0.432	0.349
N		1,913		

Note. Robust standard errors in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$. The recycling data had one missing value. The pretreatment means in the second column represent the means of dependent variables in the pretreatment periods, which were before all districts implemented the program.

ever, we do not observe an obvious upward pattern in the amount of waste in nearby cities (Taipei, Keelong, and Taoyuan City) in Figures 3-1 and 3-2.

D. Effect on Nonindustrial Water Usage

This study evaluates the effect of the unit-pricing program on nonindustrial water usage, which has not been studied in the literature. Households might use more water as a result of the unit-pricing program. For example, people may use more reusable utensils instead of disposable tableware to reduce waste. This change in behavior would increase water usage[2] and undermine the environmental protection purpose of unit-pricing programs.

We use data from the Climate Change Information System (Environmental Protection Administration, Taiwan, 2018a). Monthly nonindustrial water usage per person was approximately 6.6 kℓ (1,750 gallons) before the program was adopted. By substituting the dependent variable in regression equation (1) with monthly per capita nonindustrial water usage, we observe no significant effect of the bag program on water usage. Results are presented in Table 6.

Table 6: Estimated Effects on Monthly Per Capita Nonindustrial Water Usage (kℓ)

Program Stage	Pretreatment Mean	(1) Without Control Variables & FE	(2) With Control Variables	(3) With Control Variables & FE
Notification	6.61	0.278	−0.486*	−0.243
		(0.256)	(0.229)	(0.188)
Implementation	6.56	−0.892	−0.635	−0.581
		(0.762)	(0.728)	(0.805)
Enforcement	6.58	1.151	0.814	0.735
		(0.707)	(0.698)	(0.805)
Adj. R^2		0.002	0.290	0.001
N		1,914		

Note. Robust standard errors in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$. The pretreatment means in the second column represent the means of dependent variables in the pretreatment periods, which were before all districts implemented the policy instruments.

E. Correcting Autocorrelation Program

Because this study uses 66 months of panel data, there may be a serial correlation problem in which the dependent variables in estimation are positively serially correlated, understating standard errors and over-rejecting the null hypotheses of no effect (Bertrand et al., 2004). Therefore, we aggregate the monthly data into yearly data by using the "ignoring the time series information" approach of Bertrand et al.

2 When the unit-pricing garbage disposal policy was adopted, the garbage disposal fee was removed from the water bill. Water usage responds to marginal costs, which is the unit fee of water usage. Other fixed-amount components in the water bill such as the original garbage disposal fee are irrelevant because they are fixed costs of water usage. However, the cancellation of the original garbage disposal fee might have affected water usage through other channels, as one reviewer noted.

(2004). Rather than using 66 months of data, we use the means of the monthly waste and recycling of each year for a total of six years of average monthly per capita waste and recycling data. Because the three program stages occurred within a year of each other, we examine the program implementation but omit the notification and enforcement stages. The program intervention variable is labeled P with subscript i indicating each district and t indicating each year. We also omit the year in which the program was implemented during some months but not in other months.

$$Y_{it}=\alpha P_{it}+\beta X_{it}+\delta_t+\gamma_i+\varepsilon_{it} \tag{4}$$

Table 7 presents the results after aggregating the long panel to yearly data. The magnitudes of the estimates are consistent with the sum of the three program stage statistics. This sensitivity analysis, in which we use the aggregated model that reduces the autocorrelation problem, supports our conclusion that program implementation reduced municipal waste and increased recycling.

Table 7: Correcting Autocorrelation by Collapsing Monthly Data to the Yearly Level

Dependent Variables	Pretreatment Mean	1	2	3
Monthly Waste (kg/pp)				
Implementation	16.56	−8.287***	−9.060***	−7.852***
		(0.319)	(0.943)	(0.338)
Adj. R^2		0.776	0.846	0.914
N			145	
Monthly Recycling (kg/pp)				
Implementation	7.90	3.352***	0.988	3.734**
		(0.576)	(1.182)	(0.531)
Adj. R^2		0.147	0.530	0.539
N			145	
Control variables			✓	✓
District FE				✓

Note. Robust standard errors in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$. The pretreatment means in the second column represent the average monthly garbage and recycling in the pre-treatment periods, which were before program implementation.

VII. Discussion and Conclusion

This study used panel data of monthly average municipal waste from 29 districts of New Taipei City to ascertain the effects of a unit-pricing bag program, asking whether the program effectively reduces municipal waste. The panel data included 66 months from July 2007 to December 2012 with 1,914 observations in total. District fixed effects and time fixed effects were used in the study, and we controlled for district- and month-level covariates. By using district-level panel data and the fixed effects, our approach was able to avoid the limitations of cross-sectional municipal data, household panel data, and route-level panel data (such as bias among different municipalities, selection bias of low response rates, or lack of controlling socioeconomic characteristics).

Consistent with the literature on both Western and Asian countries (Dijkgraaf and Gradus, 2004; Van Houtven and Morris, 1999; Miranda et al., 1994; Usui and Takeuchi, 2014; Dijkgraaf and Gradus, 2017; Hong, 1999; Kuo and Perrings, 2010; Kuo, 2009), our results indicated that the bag program significantly reduced waste and increased recycling. Monthly per capita waste was reduced by approximately 7 kg (40% of the pretreatment mean), and recycling increased by 1.5 kilograms (15% of the pretreatment mean) after program implementation. The result is similar to Dijkgraaf and Gradus's (2004) research, in which solid waste was reduced by 51% in the Netherlands. Our results were also similar to another Asian study that indicated that the magnitude of the effect increased from 8% to 57.4% in most Korean cities implementing a unit-pricing program (Hong, 1999). This effect was larger than that observed by Tsai and Sheu (2009), who demonstrated a 22% waste decrease in Taipei City.

Although the magnitude of the increased recycling was not large (less than 20%) compared with the substantial decrease in waste, it is consistent with literature that has demonstrated a 16%–21% increase in recycling weight with unit-price programs (Fullerton and Kinnaman, 1996; Dijkgraaf and Gradus, 2004). Recycling may not have increased more in New Taipei City because of a waste-sorting program requiring citizens to separate waste into resources, kitchen waste, and garbage that was implemented in 2006 before the bag program in the city as well as other recycling-related programs implemented earlier (Environmental Protection Administration, Taiwan, 2017a; Tsai et al., 2007). Because citizens had been recycling before the unit-pricing program, they had few opportunities to recycle more as a means of diverting waste. Tsai and Sheu (2009) suspected that the insignificant effect of unit pricing on recycling was due to the national recycling program implemented in 1997.

By contrast, a larger increase in recycling (26.8%) was demonstrated in Hong (1999) because of Korea's accompanying aggressive recycling programs.

If the reduced waste was not fully diverted to recycling, where did the waste transfer to? To understand the mechanism, we evaluated the illegal dumping concern. We did not observe a significant illegal dumping problem in nearby districts or even nearby cities, as Figure 3 demonstrates. The insignificant illegal dumping problem is consistent with previous literature (Miranda et al., 1994; Allers and Hoeben, 2010; Kuo, 2009). Moreover, we did not observe an increase in water usage after program implementation. This provides evidence that the unit-pricing program did not have an adverse effect of increasing water usage.

However, the lack of illegal dumping observed in our study appears to contradict the findings of Tsai and Sheu (2009), who observed substantial illegal dumping in Taipei's neighboring area of New Taipei City. People frequently commute between Taipei City and New Taipei City because many citizens live in New Taipei but work in Taipei or vice versa (Tsai and Sheu, 2009). When Taipei City implemented the bag program in 2000, but the surrounding New Taipei City had not, illegal dumping was a convenient alternative to reducing payments. After both cities implemented the program, no obvious increase in waste of nearby cities was observed because other cities may not have as close a relationship as that between Taipei and New Taipei City. Our conjecture requires confirmation in future research.

By combining the results, we inferred that the unit-pricing program changed citizens' behavior by reducing sources of waste and by fully diverting waste to recycling when we eliminated the possibility of illegal dumping in nearby districts. Because of the high population density in New Taipei City, people are not likely to compost or store their waste. Furthermore, we examined the autocorrelation concern by aggregating the monthly panel data to yearly panel data and eliminating the possibility of illegal dumping in other cities with city-level data. Our long-term city-level data also suggested no apparent rebound of the reduced waste in the long term. This is similar to the research of Usui and Takeuchi (2014), who demonstrated a negligible rebound effect in Japan.

One of the contributions of this study is our differentiation of program stages to assess the effects of divergent policy instruments. The results demonstrated that the implementation stage, in which citizens were refused curbside garbage service if they failed to use certified garbage bags, yielded the most significant and largest effect. The effect of the notification stage, in which the government promoted the program and encouraged citizens to use the bags, was statistically insignificant. The enforcement stage, in which citizens faced a penalty for illegal dumping, was not more effective than the implementation stage was. This contradicts our supposition that the stricter the policy tool, the more effective the outcome is. This could be due to the anticipation effect (Baumeister et al., 2007) in which citizens anticipate being fined at the implementation stage, or it may be that compared with the penalty fine, being refused curbside garbage service is a sufficient disincentive because citizens may have no alternative means of discarding their waste.

The policy implications of this study are as follows: First, because the unit-pricing bag program effectively reduced waste in high-density New Taipei City, policy makers in other high-density areas in Asian cities, particularly other municipalities in Taiwan, should consider adopting this program. Other Taiwanese cities are considering the garbage bag program (Yang, 2016), and this study provides supportive evidence for decision makers who are considering the program as an impetus to reduce waste. Second, policy makers need not be concerned about the side effects or adverse effects of the unit-pricing bag program, such as illegal dumping, increased water usage, or rebound effects in the long term. Third, nearby cities should implement the program simultaneously to prevent the illegal dumping problem. Our research indicated no illegal dumping in New Taipei City, whereas Tsai and Sheu (2009) concluded that waste reduction in Taipei City was due to illegal dumping to neighboring areas (i.e., New Taipei City). The results of both studies imply that implementing the unit-pricing program simultaneously with nearby regions is likely to result in waste reduction without illegal dumping. Fourth, only advertising the program is insufficient. Citizens were more willing to reduce waste when they were not allowed to discard waste curbside in the implementation stage or faced a penalty for not using the certified bags. Policy makers should consider using stringent policy tools to achieve effective results.

VIII. Research Limitations and Future Research

This study has a few limitations. First, because people might illegally discard waste in the countryside, an overestimation of the program effect might have occurred. Parts of the New Taipei City coastline are surrounded by the sea, and mountains occupy many New Taipei City districts. Although we did not observe illegal dumping in districts and cities, some citizens may have discarded their waste in the countryside; such dumping would not have been detected in this study.[3] However, we argue that the problem of discarding waste in the countryside is negligible because no related events were revealed in public media or social media, which are

3 Waste discarded directly in the countryside would not have been collected by garbage trucks. Therefore, it could not be included in the data or detected in this study.

considered highly developed in Taiwan. We inferred that this type of illegal dumping was not severe even if it occurred.

Second, some buildings or neighborhoods contract waste disposal companies to process their waste. Thus, residents need not discard their waste curbside. This type of information may not be included in our data. Consequently, this problem would affect our estimates. However, we believe this was a minor concern in our study because the waste processed by contractors is a small portion of the waste in New Taipei City, and the number of contracts would not change considerably in our short-term monthly district panel data. Third, although this study used district fixed effects to control for unobservable time-invariant characteristics and year and month fixed effects to control for time trends, unobservable time variant factors at the district level may have confounded our results.

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單位定價方案對都市垃圾量之影響——以新北市為例

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摘　　要

本文旨在探討新北市採取垃圾隨袋徵收一單位定價方案之效果。本文利用2007 年 7 月至 2011 年 12 月新北市各區的縱橫資料（panel data），以固定效果模型進行垃圾量和回收量的分析。研究發現新北市採行單位定價方案後，每月人均垃圾量大幅減少 40%，而回收量增加 15%。另以 2000 年到 2017 年的市級數據看來，在隨袋徵收政策之後，垃圾量長期而言並無明顯的反彈趨勢。鑒於本文之各項檢測皆顯示一致的結果，作者認為垃圾隨袋徵收一單位定價方案確實能有效降低垃圾量，本文研究結果將得以提供高人口密度都市採行垃圾減量方案之參考。

關鍵字：環保政策、垃圾袋、方案評估、單位定價系統、垃圾處理

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