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The Crowding-Out Effects of Garbage Fees and Voluntary Source Separation Programs on Waste Reduction: Evidence from China

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Abstract: This paper examines how and to what degree government policies of garbage fees and voluntary source separation programs, with free indoor containers and garbage bags, can affect the effectiveness of municipal solid waste (MSW) management, in the sense of achieving a desirable reduction of per capita MSW generation. Based on city-level panel data for years 1998–2012 in China, our empirical analysis indicates that per capita MSW generated is increasing with per capita disposable income, average household size, education levels of households, and the lagged per capita MSW. While both garbage fees and source separation programs have separately led to reductions in per capita waste generation, the interaction of the two policies has resulted in an increase in per capita waste generation due to the following crowding-out effects: Firstly, the positive effect of income dominates the negative effect of the garbage fee. Secondly, there are crowding-out effects of mandatory charging system and the subsidized voluntary source separation on per capita MSW generation. Thirdly, small subsidies and tax punishments have reduced the intrinsic motivation for voluntary source separation of MSW. Thus, compatible fee charging system, higher levels of subsidies, and well-designed public information and education campaigns are required to promote household waste source separation and reduction.

Keywords: waste generation; garbage fee; waste source separation; crowding-out effects

1. Introduction

Municipal solid waste (MSW) has been challenging the policy design of environment management around the world, especially for the fast growing cities in developing countries [1–3]. To fight against environmental pollution arising from MSW, both pay-as-you-throw (PAYT) systems under the polluter pays principle [4–7] and source separation of MSW [8,9] have been widely practiced in developed countries. In recent years, some developing country authorities have adopted these two policy instruments to alleviate their burgeoning solid waste problem without careful consideration of the country's particular socio-political circumstance and tradition [10], although the practical effects of waste charging systems and recycling programs across municipalities are still far from consensus [11]. A growing body of literature has been conducted to investigate the effects of waste management policies on increasing recycling and reducing waste in developed countries. For example, Hong [12] studies the impact of waste charging system on household waste management by employing a cross-section data model and finds that an increase in waste collection fee induces households to recycle more wastes and reduce total waste generated. A similar result is also reported by Allers and Hoeben [13], who apply a differences-in-differences regression model to estimate the effect of waste charging system on household waste quantities and recycling. While the majority of these studies have been restricted to single policy analysis, several studies have attempted to examine waste charging system and recycling program together. Based on a cross-sectional data model, Kinnaman and Fullerton [14] argue that PAYT systems have significantly reduced waste generation but that recycling programs are relatively ineffective. In contrast, Jenkins and Martinez [15] and Park and Berry [16] document that recycling programs rather than unit pricing system have enhanced the recycling rate through a similar cross-sectional multiple regression analysis. Inconsistent with both the foregoing results, Sidique et al. [17] and Lakhan [18] conclude that both variable pricing and recycling programs have effectively increased the recycling rate of MSW.

These important researches, however, have not taken the existing policies might interact with each other into consideration, which might be an important potential reason that they come to different or even contradictory conclusions. Recently, in a closely related paper, employing a panel data approach, Starr and Nicolson [19] have found that curbside recycling program alone has an insignificant effect on municipal recycling rate, but by combining curbside recycling program with PAYT system the interaction boosts municipal recycling rate higher than either policy can individually. Actually, the interactive effect of policy interventions on individual motivation for pro-social behavior, such as waste reduction behavior, has always been a controversial issue [20,21]. Some assume that the effects of intrinsic motivation and extrinsic rewards on performance are additive [22], but others argue that linking extrinsic rewards to task performance will undermine intrinsic motivation ("crowding out") and therefore decrease performance [23–27]. While previous researches on waste management have highlighted the important roles of policy interventions in waste reduction, most studies have mainly focused on waste charging system and waste recycling program in developed countries, and the existing literature concerned with quantitatively analyzing waste management policies in developing countries is quite limited [28]. Under a significantly distinct socio-political context, comprehensively understanding the effectiveness of intervention programs in developing countries requires abundant corresponding studies.

As the most populous and largest developing country, along with fast urbanization and industrialization, the climbing MSW of China has become an urgent threat to environmental safety and human health [29,30]. Although a flat-rate fee was initiated in the middle of the 1990s, and a voluntary source separation program of MSW with a small subsidy was put forward in June of 2000 at eight pilot cities, due to inadequate waste disposal equipment and poor disposal habits of households [31], the overall reduction effect of the pilot program of MSW source separation is unsatisfactory [32]. In fact, the stakes for the success of MSW mitigation programs in developing countries are proving to be higher than expected [33] and their effectiveness in reducing waste generation is more uncertain [34]. Although the crowding-out effect has been a debated issue in motivation theory, it is believed to be of little empirical relevance from the perspective of economics [21]. For example, existing literature concerning private and public provision of public goods generally ignores the distortionary effects of income tax like crowding-out effect [35]. A thoughtful understanding of whether the policy instruments are reasonably designed and compatibly combined is critical for policy designers. Fortunately, the diversity of Chinese cities, with varying economic, social, and policy conditions, offers a fruitful avenue for the present research.

This study extends the literature by applying panel data models to examine the interactive effect of a voluntary source separation program associated with a small subsidy and a garbage fee system on MSW generation in China, along with the effects of income and demographic variables. One of the key features of this study is that we comprehensively analyze the combination effect of waste charging system and waste source separation grogram on waste generation in China, which could timely provide practicable highlights for policy design in waste management in transitional China and other developing economies. Another feature of this study is the use of both a static panel model and a dynamic panel model. Compared to most of previous studies based on cross-sectional data model, the panel model of this study enables analysis of dynamic time-variant effects and captures the persistence of waste emission caused by unobservable characteristics like habits and customs.

In addition, using two types of panel model provides a consistency check on whether the estimation result is robust or not by comparing the coefficients of each model.

2. The Evolving Regulatory System and Present Situation of MSW in China

2.1. Evolution of MSW Regulatory System

In China, the key national legislation specifically pertaining to waste management is the Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste (hereinafter referred to as the Law on Solid Waste), which was enacted in 1995 and amended in 2004, 2013 and 2015. The law explicitly stipulates the basic provisions of waste management, waste administration and supervision, pollution prevention and control measures, and associated legal responsibilities for violations, thereby has laid the legislative foundation for waste management system. Under this law, a set of administrative regulations and policies were passed by relevant departments of the State Council, including the Notice on Releasing the List of Pilot Cities Pertaining to Municipal Solid Waste Source Separation (2000), the Notice on Charging Urban Waste Treatment Fee and Promoting the Industrialization of Waste Treatment (2002), Administrative Measures for Municipal Solid Waste (1993; amended in 2007 and 2015), and Administrative Measures for Renewable Resource Recycling (2007).

Apart from laws and regulations, the Chinese government has also issued a series of technical specifications and pollution control standards pertinent to waste management. For waste collection and transportation, it includes the Classification and Evaluation Standard of Municipal Solid Waste (CJJ/T102-2004), the Technical Specification for Municipal Solid Waste Collecting Station (CJJ179-2012), and the Technical Specification for Collection and Transportation of Municipal Solid Waste (CJJ205-2013). For waste treatment and disposal, it includes the Technical Specification for the Composting of Municipal Solid Waste (CJJ 52-2014), the Pollution Control Standard for Municipal Solid Waste Landfills (GB 16889-2008), and the Pollution Control Standard for Municipal Solid Waste Incineration (GB 18485-2014). All these documents have successfully provided basic legal constraint and useful process guidance on waste management.

2.2. Waste Generation and Collection

Along with fast urbanization and industrialization, the amount of solid waste has increased rapidly in China. Figure 1 displays the climbing patterns of industrial and municipal solid wastes for the years 1998–2012. The quantity of MSW collected and transported had increased from 113.02 tons in 1998 to 170.81 million tons in 2012 and the quantity of industrial solid wastes generated had increased from 800.68 tons to 3290.44 tons correspondingly. Although the amount of MSW collected and transported is smaller than that of industrial solid waste, given the high recycling rate of homogeneous industrial solid waste, heterogeneous MSW has emerged to be a comparatively critical issue for waste management in China [36]. Currently, MSW is still collected in a mixed way in most cities, although waste source-separated collection can enhance opportunities for composting and recycling and reduce wastes that go to dumpsites and landfills. Consequently, recyclables and kitchen waste are polluted and their values are reduced or even lost. However, there are a few exceptions. Eight pilot cities involved in waste source separation program have implemented waste source-separated collection, albeit to different extents.

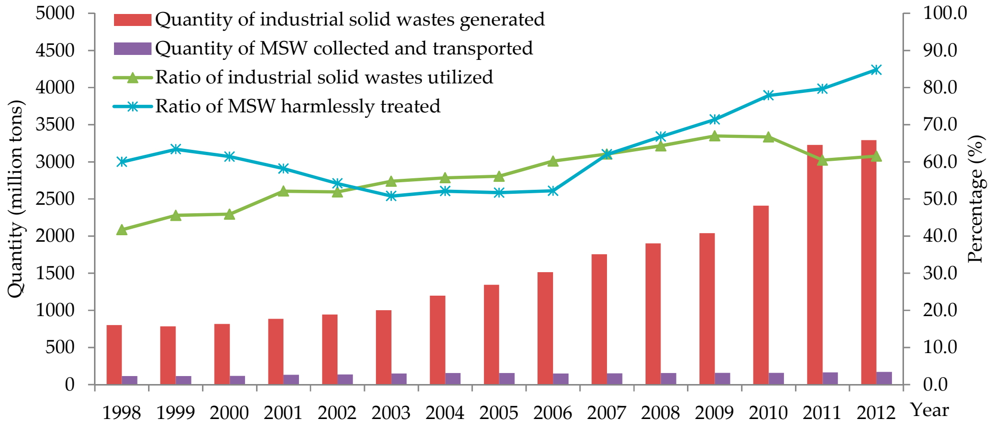

Figure 1. The composition of solid waste between 1998 and 2012 in China (source: National Bureau of Statistics of China, 1999–2013 [37]).

2.3. Waste Treatment and Disposal

The introduction of laws and regulations concerning waste management, along with the implementation of pollution control standards for MSW disposals, decreased the percentage dumped at appointed sites, denoted as the difference between MSW collected and transported and MSW harmlessly treated, from nearly half to 15.17% in 2012 (see Figure 1). Especially after the Law on Solid Waste came into effect in 1996, the percentage of industrial solid wastes reutilized increased from 41.7% in 1998 to 61.5% in 2012, and the percentage of MSW harmlessly treated, consisting of wastes disposed by sanitary landfill, incineration and composting, increased from 60.0% in 1998 to 84.9% in 2012. Due to the physical requirements for different modes of waste disposals, the classification of MSW into composting materials, combustible materials, and recyclable materials is a necessary precondition for the effective utilization of MSW [38]. For example, high temperature compost could only be applied to the biodegradable refuse when the organic matter content of refuse is higher than 40%, and incineration is only applicable when the average low heat value of refuse is higher than 5000 kJ/kg. As shown in Table 1, while the amount of incinerated MSW (measured in ten thousand ton intervals) increased from 370 in 2003 to 3584 in 2012, and the amount composted decreased from 717 in 2003 to 393 in 2012, the amount disposed of in sanitary landfills increased from 6404 in 2003 to 10512 in 2012. Because of the cruder waste source separation systems, sanitary landfill is still the major mode of refuse disposal in China, with 72.55% of MSW disposed of in this manner in 2012.

Table 1. Municipal solid waste (MSW) disposals in China (10,000 tons) (source: National Bureau of Statistics of China, 2004–2013 [37]).

Year	Volume Dumped at Appointed Sites	MSW Collected and Transported	Sanitary Landfill		Incineration		Composting		MSW Harmlessly Treated	
			Volume	Ratio [a]	Volume	Ratio [a]	Volume	Ratio [a]	Volume	Ratio [b]
2003	7366	14,857	6404	85.49%	370	4.94%	717	9.57%	7491	50.42%
2004	7441	15,509	6889	85.39%	449	5.57%	730	9.05%	8068	52.02%
2005	7583	15,577	6857	85.78%	791	9.90%	345	4.32%	7994	51.32%
2006	7007	14,841	6408	81.80%	1138	14.52%	288	3.68%	7834	52.79%
2007	5897	15,215	7633	81.92%	1435	15.40%	250	2.68%	9318	61.24%
2008	5270	15,438	8424	82.85%	1570	15.44%	174	1.71%	10,168	65.86%
2009	4635	15,734	8899	80.17%	2022	18.22%	179	1.61%	11,099	70.54%
2010	3709	15,805	9598	79.35%	2317	19.15%	181	1.49%	12,096	76.53%
2011	3845	16,935	10064	76.88%	2599	19.86%	427	3.26%	13,090	77.29%
2012	2591	17,081	10512	72.55%	3584	24.74%	393	2.71%	14,490	84.83%

[a] Ratio to MSW harmless treated; [b] Ratio to MSW collected and transported.

2.4. Voluntary Source Separation Program Paired with Fee Charging System

To facilitate the classification of MSW at sources, the Notice on Releasing the List of Pilot Cities Pertaining to Municipal Solid Waste Source Separation was released on 1 June 2000 under the guidance of the former Ministry of Construction of China. Eight cities, namely Beijing, Guangzhou, Shanghai, Shenzhen, Xiamen, Hangzhou, Nanjing, and Guilin, were chosen as pilot samples. Initially, dry and wet separation was practiced in all pilot cities, which has evolved into different modes of waste sorting categories today across pilot cities. In Guangzhou, Shenzhen, Hangzhou, and Nanjing, MSW is broadly separated into four categories: recyclables, kitchen waste, hazardous waste and others. Shanghai employs a four-category classification system of recyclables, hazardous waste, and wet and dry wastes. In Beijing and Guilin, households are encouraged to separate waste into recyclables, kitchen waste and others, while waste is mainly sorted into hazardous waste, kitchen waste, and others in Xiamen. Generally speaking, wet and dry separation is voluntarily practiced in all piloting cities. Though source separation has been promoted as a key priority for waste diversion in China [39], it still stayed at the initial stage due to the limitation of financial resources from local government, underdeveloped equipment and facilities, absence of regulations and sanction measures, missing market of source classification, and poor performance of recycling systems [40–42]. As a result, the accumulated amount of MSW in China occupied 50,000 hectares of land in 1998 [43], and more cities were caught in the garbage siege.

To ameliorate the financial constraint of waste management and provide economic incentives for households to engage in solid waste reduction, the Notice on Charging Urban Waste Treatment Fee and Promoting the Industrialization of Waste Treatment was issued in 2002. The charging system is a flat rate scheme with varying rates across cities. Figure 2 shows that there are different patterns of per capita MSW, with substantially varying garbage fees. In Shenzhen, Hangzhou, and Shanghai, the per capita MSW presented a short-term downward trend immediately after the implementation of waste source separation in 2000, while the per capita MSW displayed a long-term upward trend for Beijing and Guangzhou after the implementation of waste source separation. However, the per capita MSW has accelerated with a steady growth all the time in Xiamen, Guilin and Nanjing; the highest fee levied in Guangzhou has not led to the lowest per capita MSW; while Guilin has the lowest per capita MSW with a medium-level fee (see Figure 2). The flat-rate fee system alone has not led to a reduction of waste generation in pilot cities except in Shenzhen.

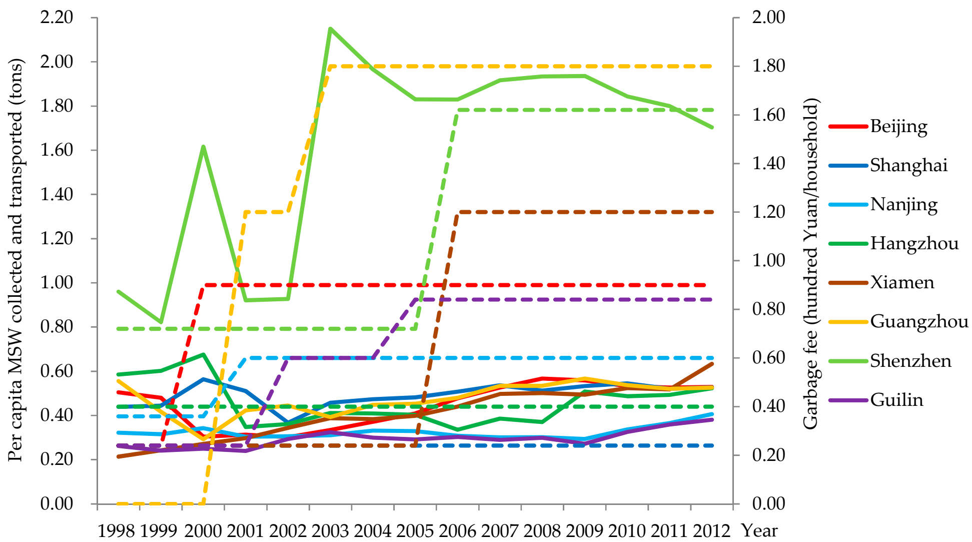

Figure 2. Relationship between garbage fees and per capita municipal solid waste (MSW) in eight pilot cities (Source: National Bureau of Statistics of China, 1999–2013 [44]). Notes: The dashed line denotes garbage fee and the solid line denotes per capita MSW collected and transported.

As a consequence of a rapidly urbanizing population and improved living standards, affluent Chinese are already among the world's largest waste generator [31]. Chinese authorities are incapable of preventing the waste stream from growing and all they can do is to slow down the rate of growth [45]. Given the fact that recyclable wastes account for 8%–10% of MSW in China [46], resourcing MSW has emerged as a critical strategy for resolving the issue of environmental pollution of growing MSW. However, the effects of source separation and charging system on per capita MSW in China vary across piloting cities, and so the conflict between theoretical and observation findings deserves a deep analysis of the factors underlying the patterns of per capita MSW generation. Understanding the potential causes for the different impacts of combined voluntary source separation with small subsidies and price policy on the generation of per capita MSW is necessary to provide useful insights for policy makers. We now turn to an empirical examination of the interactive effects of policies on MSW generation with socioeconomic variables, attempting to identify the factors responsible for the rising trends of per capita MSW.

3. Materials and Methods

3.1. Econometric Model

Compared to conventional cross-sectional or time series data model, panel data model possesses several major advantages such as reducing the multicollinearity among explanatory variables, controlling the impact of omitted variables, allowing for heterogeneity between individuals, more accurate inference of model parameters, and uncovering dynamic relationships [47], which can successfully satisfy our research needs for econometric method. We therefore employ a static panel data model as follows to investigate the impact of a policy mix of subsidized source separation and garbage fee on waste generation:

$$Waste_{it} = \alpha_i + \gamma Separation_{it} + \rho Fee_{it} + \delta Separation \times Fee + \beta X_{it} + \varepsilon_{it} \quad (1)$$

where $Waste_{it}$ is per capita MSW collected and transported for city i in year t. Following the definition given by the World Bank, MSW here consists of residential, institutional, commercial, street cleaning, and non-process waste from industries [45]. Although "waste generated" data are more useful since it covers recyclable secondary materials that have sorted by consumer units, "waste collected and transported" data are statistically available in China. This is an expedient enforced by limitations of data. Therefore, MSW refers to the weight of MSW collected and transported in this study.*Separation* is a dummy variable indicating the phase of source separation policy which equals zero for years before the city started implementing the source separation policy and one for the first implementation year and all subsequent years; Fee_{it} is the yearly payment of each household for waste service in city i in year t; X_{it} is a set of other potential covariates, including per capita disposable income, household size, dependency rate, and education level; α_i is the time-invariant and city-specific effect; ε_{it} is an error term with $E(\mu_{it}) = 0$ for all i and t, capturing all other omitted factors; and γ, ρ, δ and β are parameters to be estimated.

However, in addition to the standard error component assumption, a static panel data model usually requires that all the explanatory variables are strictly exogenous. Although the ordinary panel data model allows us to control for the endogeneity of source separation and garbage fee stemming from their correlations with the city and year fixed effects, it does not control for the endogeneity caused by the correlation of the source separation and garbage fee policies with the unobserved time-variant city characteristics in ε_{it}. In addition, the quantity of MSW generated per capita may exhibit persistence over time, as human behavior and lifestyle are unlikely to change dramatically during a short period of time. Thus, we construct a dynamic panel data model as follows with the quantity of lagged MSW collected and transported per capita as explanatory variables:

$$Waste_{it} = \alpha_i + \gamma Separation_{it} + \rho Fee_{it} + \delta Separation \times Fee + \beta X_{it} + \lambda Waste_{it-1} + \varepsilon_{it} \quad (2)$$

where $Waste_{it-1}$ is the lagged quantity of MSW collected and transported per capita. In order to arrive at unbiased and consistent estimates of the coefficients, the generalized method of moments (GMM) procedure proposed by Arellano and Bond [48] was employed to estimate model (2).

3.2. Variables and the Data

Source separation is considered as an effective way of reducing waste and enhancing recycling in many developed countries as mentioned in previous section. On 1 June 2000, eight pilot cities were chosen to explore source separation programs. In pilot cities, multiple free indoor containers and garbage bags are provided to encourage waste separation practices of households.

In China, the Administrative Measures for Municipal Solid Waste (1993) explicitly stipulated that the entities and individuals producing MSW should pay fees for MSW services. A notable fact is that the charge rates and the time periods of garbage fee collection differ considerably across cities. Thus, the garbage fee variable is annual payment of households at given cities and years.

We include per capita disposable income, average household size, average dependency rate, and average education as control variables affecting household action in solid waste disposal in our analysis, following previous studies. It is believed that waste generated increases along with the improvement of living standards [2]; waste generation scales less than linearly as household size increases [49,50]; the dependency rate may result in different patterns of waste generation since households with dependents have very different consumption patterns compared to households with only working people [51]; while residents with higher education levels will have higher environmental awareness and produce less waste [52], the relationship between education and MSW generation is not definite [53]. Community and demographic characteristics, recycling policies, and public involvement in policy design will affect public participation in solid waste recycling [54].

In our econometric analysis, the disposable income denotes per capita income of urban households after income tax, and household size means average household size of urban households, which are directly replicated from the statistical yearbook. Dependency rate is computed as the ratio of average household size of urban households to average employed persons of urban households minus one. Education levels are designated as the weighted average schooling years at districts within cities, and the weights are the proportions of students with 16, 12, 9, or 6 schooling years to the district's total population. Waste is the per capita MSW collected and transported, which is calculated as MSW collected and transported divided by the urban population, in turn defined as the number of individuals who reside in cities and counties at year-end.

Time-series cross-sectional data are used to test the impact of the policy mix of subsidized source separation programs and garbage fees on waste generation. The data come from two sources: one is government documents issued by relevant cities, and the others are the statistical yearbooks, namely China City Statistical Yearbook, China Urban Construction Statistical Yearbook, and China Statistical Yearbook for Regional Economy [44,55,56]. Detailed yearly observations of 35 major cities throughout the period 1998–2012 are gathered. There are 36 Major Chinese Cities prescribed by the National Bureau of Statistics of China, which have relatively similar socio-economic characteristics and policy circumstances. Due to the incompleteness of the data, Lhasa City is removed and the other 35 cities entered in the econometric model are displayed in Figure 3. However, Urumchi City, Haikou City, and Changsha City started to levy the garbage fee on the basis of the water fee in 2008, 2011, and 2012, respectively. Therefore, eight observations of garbage fees are missing. The number of observations is 517 after observations with missing data are dropped.

Figure 3. Geographic distribution of sampled cities.

Table 2 shows definitions, averages, and standard deviations of the variables used in the analysis. Per capita MSW collected and transported is 0.419 tons per year, the annual household payment for waste disposal services is 55 Yuan per year, and per capita disposable income is 14,350 Yuan. There is an almost homogeneous component of households in terms of household size and dependency rate.

Table 2. Summary statistics for variables.

Variables	Definition	Mean	Std. Dev.
Waste	Per capita MSW collected and transported (ton)	0.419	0.249
Separation	City implements source separation program or not (dummy)	0.160	0.367
Fee	Annual fee for waste disposal services per household (100 Yuan)	0.542	0.368
Disposable income	Per capita disposable income of urban households (10,000 Yuan)	1.435	0.783
Household size	Average household size of urban households (person)	2.950	0.174
Dependency rate	Average proportion of dependents on employed persons per household (ratio)	0.929	0.188
Education	Average education level of districts under city (ratio)	2.191	0.771

4. Results and Discussion

4.1. Model Summarization

One important issue needs to be addressed before econometric analysis is the panel stationarity tests because standard regression analysis requires all variables in regression equation are stationary. In the present study, Lin and Chu (LLC) [57] and Im-Pesaran-Shin (IPS) [58] panel unit root tests are used since they have better results compared to other tests in small samples and are widely used in the relevant literature. The evidence suggests that all variables reject the null hypothesis of a unit root in both the two tests with the exception of disposable income only reject the null hypothesis in LLC test at conventional significance levels, thereby basically in favor of the alternative that all variables are stationary at level. In fact, as our panel consists of 35 cities and spans the period between 1998 and 2012, the relatively short time dimension allows us to reduce the concerns on the stationarity property of the variables [59].

The estimation results are reported in Table 3. Columns (1)–(4) summarize the baseline results of estimation of Equation (1). Columns (1) and (3) use source separation program, garbage fee, disposable income, household size, dependency rate, and education level as regressors, while columns (2) and (4) employ a broader specification which also incorporates the interaction term of source separation program and garbage fee. A relatively parsimonious regression of the interaction of these policies on per capita waste is first displayed, which has controlled heteroscedasticity and potential correlations across observations both over time and within the same period. While feasible generalized least squares (FGLS) estimator is more efficient than clustered generalized least squares (GLS) estimator, its validity depends heavily on the assumption of consistent estimator of the covariance matrix of the disturbance. We therefore present estimation results using clustered GLS, which is applicable to the more general case. As GLS (including both FGLS and clustered GLS) assumes that strong exogeneity between the explanatory variables and disturbance term might lead to biased estimators, the columns (5) and (6) display the estimation results of Equation (2) employing difference generalized method of moments (GMM) estimators, which adds the lagged per capita waste collected and transported. The two GMM regressions treated the source separation and garbage fee as predetermined and used robust standard errors clustered at the city-level.

Table 3. Estimation results for the panel data model.

Variables	**FGLS**		**Clustered GLS**		**Difference GMM**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Separation	−0.017 (0.016)	−0.036 (0.029)	−0.097 (0.085)	−0.100 * (0.056)	−0.125 (0.105)	−0.314 ** (0.157)
Fee	−0.006 (0.012)	−0.029 ** (0.013)	−0.015 (0.036)	−0.066 * (0.034)	−0.020 (0.077)	−0.221 * (0.120)
Separation × Fee		0.069 (0.043)		0.271 ** (0.124)		0.410 ** (0.178)
Disposable income	0.046 *** (0.008)	0.044 *** (0.008)	0.030 ** (0.014)	0.030 ** (0.013)	0.032 *** (0.008)	0.029 ** (0.014)
Household size	0.115 *** (0.035)	0.115 *** (0.035)	0.295 *** (0.098)	0.264 *** (0.099)	0.128 ** (0.061)	0.132 * (0.076)
Dependency rate	0.016 (0.017)	0.018 (0.018)	−0.007 (0.044)	0.009 (0.043)	0.063 (0.043)	0.068 (0.046)
Education	0.017 ** (0.007)	0.013 * (0.007)	0.047 ** (0.019)	0.048 ** (0.021)	0.038 ** (0.018)	0.037 * (0.021)
Constant	−0.061 (0.115)	−0.050 (0.115)	−0.614 * (0.319)	−0.500 (0.321)		
Lag1 waste					0.229 ** (0.117)	0.188 * (0.104)
Lag2 waste					−0.015 (0.062)	−0.050 (0.058)
Sargan test					1.000	1.000
AR(1) test					0.126	0.106
AR(2) test					0.359	0.362
Prob > chi2	0.000	0.000	0.000	0.001	0.000	0.000
Observations	517	517	517	517	412	412

Notes: Figures in parentheses are standard errors. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

The consistency of the GMM estimators depends on three assumptions: the stationarity of the dependent variable, satisfied as mentioned earlier; the validity of the instruments; and no serial correlation of the error terms. For the latter two assumptions, we use two specification tests suggested by Arellano and Bond [48]. The first is a Sargan test of over-identifying restrictions used to test the overall validity of the instruments and the second test examines whether the differenced error term is serially correlated. As shown in Table 3, the Sargan statistic with a p-value of 1 for the columns (5) and (6) indicates that the null hypothesis of the validity of the over-identifying restrictions cannot be rejected. The rows for the AR(1) test and the AR(2) test report the p-values for the first and second order autocorrelated disturbances in the first-differenced equations. There is also no evidence of significant first-order serial correlation or significant second-order serial correlation for the differenced error term. This suggests that the current specification in our test statistics is appropriate. As for control variables, all regressions have consistent results in terms of coefficient signs and significances, indicating the robustness of regression results.

4.2. Empirical Results and Discussion

4.2.1. Community Characteristics and per Capita MSW

Consistent with previous studies of Benítez et al. [52] and Thanh et al. [49], people in cities with higher per capita disposable income tend to generate more waste in China. Residents in affluent cities have relatively high purchasing power and consequently higher waste generation. In contrast to earlier findings that larger households produce less MSW per capita [49,50], the average household size is positively related to per capita MSW in China. A possible reason for this discrepancy is that 80.6% of households in urban areas of China are core households in which a married couple lives together with their unmarried children [60], and unmarried children generate more waste than average among family members [61]. The effect of dependency rate on waste generation is insignificant in all regressions in China. In line with the researches of Hage and Söderholm [53] and Sujauddin and Huda [62], people with more education tend to generate more waste because they generally have better economic conditions, and are often reluctant to change their life styles despite their higher environmental awareness.

In particular, more attention should be given to the positive impact of the lagged per capita MSW on per capita waste generation. It is believed that the voluntary participation of individuals into environment programs is driven primarily by their habits that value environmental conservation. However, in Beijing, only 52% of residents, who are overwhelmingly in favor of source separation of MSW, have participated in such programs [63]; the source separation rate is only 45.1% in Shanghai [64], and the separation rate is less than 15% in the other six pilot cities [39]. By contrast, all households in Germany are required to separate their domestic waste into categories of paper, glass, light-packaging, biodegradable, and others [65], and the corresponding recycling rate there rose from about 10% in 1992 to over 40% in 2007 [66]. The lack of public participation resulting from mixed waste collection habits is likely responsible for the ineffectiveness of MSW source separation policy on waste reduction, and it will take time for individuals to foster habits of waste source separation.

4.2.2. The Effects of Source Separation and Garbage Fee Systems

In discordance with the success of waste source separation in reducing MSW generation in industrialized countries [10,31], the coefficients of voluntary source separation are insignificantly negative, indicated by columns (1), (3) and (5) in Table 3. One potential explanation for this discrepancy might lie in the context of the voluntary policy. The aim of a voluntary program in industrialized countries is to encourage firms to overcomply with mandatory regulations, while it is expected to help remedy noncompliance with mandatory regulation in developing countries [33]. Enforcing mandatory regulation is a challenging issue in developing economies because of weak institutions, incomplete legal foundations, and limited political will [67]. In the absence of mandatory regulations, the lack of public consciousness and public participation in China has to some extent led to the frustrating performance of voluntary source separation program of MSW. In addition, as mentioned in Section 2.4, this disappointing effect may also attribute to the lack of sorting facilities and underdeveloped recycling system. Without an abundant and convenience infrastructure to make the sorting behavior easier, sorting will not increase. Therefore, Chinese governments, not only central government, but especially local initiatives, on the one hand will need to take an active role in increasing overall public awareness about waste minimization through well-designed educational and publicity programs and on the other hand should thoughtfully provide adequate and convenient sorting facilities and supporting infrastructure.

The efficacy of waste charging system in increasing recycling and reducing waste generation has been a contentious issue in early research [12,13,61,68–70]. In the present study, Garbage fee enters the waste generation equations with a negative sign but is uniformly insignificant across the columns (1), (3) and (5) in Table 3 at the 10% level. This finding may be explained as follows. Unlike in developed countries where the PAYT system is a powerful instrument to increase waste separation and recycling behaviors [4,5], in China, the flat-rate fee system, applied on a basis of per unit area of properties for households, in which the marginal cost of producing one more unit of waste is zero fails to provide sufficient economic incentive for waste separation and recycling [31,71]. A more incentive-compatible charging system should be designed to attract more people to engage in waste sorting. For example, decrease or remit the garbage fee for households who have separated their wastes correctly.

4.2.3. The Interactive Effect of Source Separation Programs and Garbage Fees

The crowding-out effects of source separation programs and garbage fees refer to the possibility of intrinsic reduction of waste source separation induced by these external interventions. From columns (4) and (6), the coefficients of interaction terms between source separation program and garbage fee are significantly positive at the 5% level. In contrast to the findings of previous studies in developed countries where the PAYT system and recycling program jointly induced waste reduction [72] and increased recycling rate [19], there is a positive effect of source separation program combined with garbage fee on waste generation in China. This means that waste separation program paired with garbage fee appears to crowd out individuals' intrinsic motivations for waste sorting rather than reinforce them. Several points deserve special attention:

Firstly, as a part of the income tax, the effect of the flat-rate fee on per capita MSW generated can be divided into in income effect and substitution effect. An increase in garbage fee has the opposite effect of an increase in income. The net effect of the flat-rate fee depends on the comparison of the two parts. According to our sample data, on an average, the garbage fee accounts for 0.13 percent of household disposable income. As expected, the estimated income elasticity is significantly positive while the estimated price elasticity is significantly negative, which are calculated from column (6) of Table 3. Compared with other selected countries, households in China have relatively lower income elasticity and medium price elasticity (see Table 4). As the magnitude of increasing disposable income is far more than the amount of garbage fee each household needs to pay, the effect of income dominates that of flat-rate fee, partly explaining why economic and social development still translates into upwards-sloping trends of waste generation [73]. The effect of income will partially offset that of garbage fee.

Table 4. Estimated income and price elasticities of waste generation.

	Study	Country	Level	Estimate
Income elasticity	Wertz [74]	United States	Household level	0.272, 0.279
	Hong [12]	Korea	Household level	0.088
	Reschovsky and Stone [75]	United States	Household level	0.22
	Jenkins [69]	United Kingdom	Municipal level	0.41
	Kinnaman and Fullerton [14]	United States	Community level	0.262
	Present study	China	Municipal level	0.101
Price elasticity	Wertz [74]	United States	Household level	−0.15
	Fullerton and Kinnaman [68]	United States	Household level	−0.076
	Jenkins [69]	United Kingdom	Municipal level	−0.12
	Linderhof et al. [70]	Netherlands	Household level	−0.26
	Kinnaman and Fullerton [14]	United States	Community level	−0.28
	Dijkgraaf and Gradus [76]	Netherlands	Municipal level	−0.06 to −0.47
	Present study	China	Municipal level	−0.286

More importantly, the garbage fee does not only crowd out intrinsic motivation, it even has an opposite direction effect on source separation. We compute the marginal effects of source separation and garbage fee using the results in column (6) of Table 3. In Figure 4a, the navy line plots the estimated marginal conditional effects of source separation on waste generation as a function of the garbage fee, and the hourglass shape of the confidence interval reveals the uncertainty surrounding these estimated effects. The marginal effect of source separation is at a rate of 0.410 tons of waste for each one-unit increase in garbage fee. The marginal effect of source separation is −0.314 and statistically significant when the garbage fee is zero. As the garbage fee rises from 0.284 to 1.384, the marginal effect of source separation is statistically indistinguishable from zero. Nevertheless, when garbage fee increases to 1.8 the marginal effect of source separation becomes significantly positive, 0.423. Because an economic incentive is only a weak reinforcer in the short run, but a negative reinforcer in the long run [77], the persistent erosion of intrinsic motivation [27] will discourage public participation in source separation programs, especially when respondents believe they are paying enough for professionals to do the job [78].

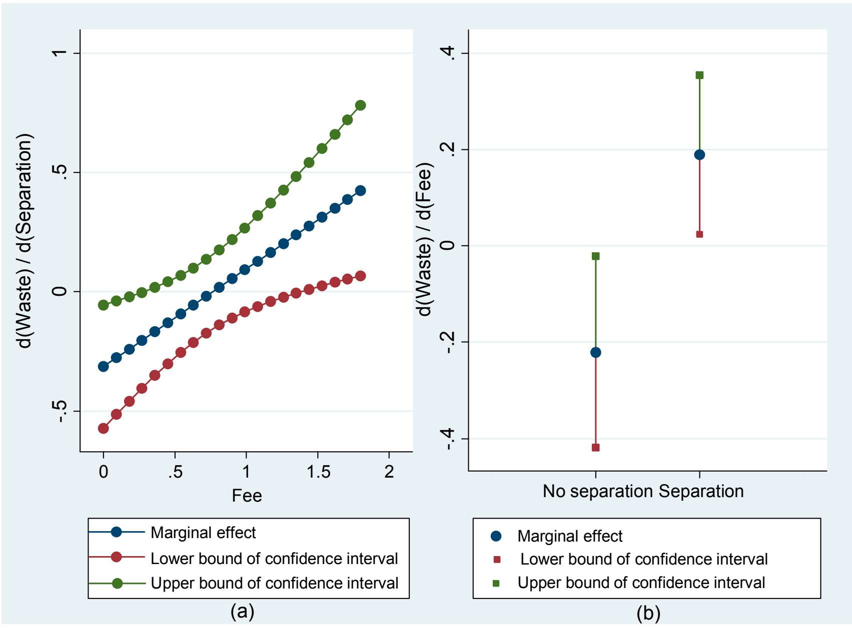

Figure 4. Marginal effects of source separation and garbage fee, with 95% confidence intervals: (**a**) marginal effects of source separation; and (**b**) marginal effects of garbage fee.

On the other hand, the effect of garbage fee on waste generation also depends on the effect of source separation. The marginal effect of garbage fee is −0.221 without a source separation program while the marginal effect is 0.189 when there exists a source separation program, and they are both significantly different from zero at conventional significance level (see Figure 4b). Households who are forced to reduce waste generation by outside intervention feel overjustified if they have maintained their inherent motivation. Therefore, it is necessary to appeal to the public's sense of shared responsibility [79,80] to encourage public involvement in source separation of MSW.

Secondly, the crowding-out effect of the mandatory charging system on per capita MSW generation deserves further attention. Traditional economics literature argues that making monetary punishments or rewards contingent on performance can induce desirable behaviors [12,14,17,18,69]. Very recently, the economics literature increasingly recognizes that individuals do not care only about monetary pay-offs, but are also concerned with non-monetary aspects [21,73,81]. The voluntary provision of waste source separation is motivated mainly intrinsically [25,27,77,82]. Income taxation has significant distortionary effects, which are more significant for higher-income households [35,83].

The crowding-out effect of the flat-rate fee on voluntary provision of public goods is enhanced with growing income.

Thirdly, the crowding-out effect of voluntary source separation on per capita MSW generation deserves special attention. Typical economic approaches generally assume performance-contingent rewards act as a positive stimulus on pursued performance [84,85]. With a corresponding reduction in intrinsically motivated effort [86], such rewards can even cause more than complete crowding-out of voluntary contributions [21,24,87]. In China, the small subsidy in terms of free garbage bags and trash containers for the sorting system just generates a crowding-out effect on people's environmental morality [23,88].

The double crowding-out effects of the garbage fee and subsidy have led to a negative impact on waste reduction in China. When public goods are paid for by distortionary taxes, then efficiency could be improved by a mixed system in which the public good is supplied by private contributions that are perhaps very heavily subsidized [89,90]. Small subsidies for waste sorting will further reduce the intrinsic motivation that has already been negatively affected by tax punishment for waste sorting actions. An elaborately designed source separation program for MSW is urgently needed.

5. Conclusions

Escalating waste generation, combined with concerns over environmental and human health, has forced the Chinese government to reform the waste management system at all levels. Policy instruments of garbage fees and waste source separation programs have been instituted to prevent recyclable materials from entering the waste stream. This paper has attempted to investigate the influences of municipal solid waste management policies on waste generation in an integrated manner.

Utilizing city-level panel data from China covering the period 1998–2012, this study empirically examined the impacts of garbage fees and source separation programs with small subsidies on per capita MSW generation, and especially focused on their combined effect. After employing both a static panel model and a dynamic panel model, this study finds that per capita disposable income, average household size and education level are major drivers of per capita MSW generation. More importantly, the findings also show that while the waste pricing system and source separation are to some extent effective in reducing waste generation, respectively, the interaction effect has increased rather than decreased waste generation. The opposite large interaction effect has almost counteracted the respective effects of source separation and garbage fee, a result that persists when using different econometric specification and estimation techniques, and is robust to the inclusion of additional covariates. The plausible explanations for the combination of waste source separation program and waste charging system has increased rather than decreased waste generation might be as follows. Firstly, the positive effect of relatively high household disposable income dominates the negative effect of the garbage fee. Secondly, there are crowding-out effects of the mandatory charging system and subsidized voluntary source separation program on voluntary source separation, and so the double crowding-out effects of the garbage fee and subsidy have led to a negative impact on waste reduction. Moreover, garbage fees inevitably reduce the intrinsic motivation of voluntary source separation because incentives are only weak reinforcers in the short run and negative reinforcers in the long run. Although traditional economics literature argues that making monetary punishments or rewards contingent on performance can induce desirable behavior, the crowding-out effect of mandatory and voluntary policies on waste generation should be taken into consideration for elaborate policy design and selection of waste management options.

The above findings have some underlying implications for China and other developing countries regarding how to design a comprehensive policy mix to increase waste separation. Firstly, the introduction of regulatory sanctions in the form of flat-rate garbage fee or small external rewards in some settings can indeed reduce household waste sorting. Therefore, although collecting flat-rate garbage fee might arouse and enlarge public awareness for waste problems, the waste charging system should be appropriately adjusted to maintain compatibility with waste source separation program with a consideration of the possible crowding-out effect. For example, establish a differentiated garbage fee charging system in which households who have separated their wastes correctly can enjoy a discount on waste service or even free for waste service. On the other hand, small external rewards by means of small subsidies associated with waste source separation in our study may ultimately be counterproductive. When sorting facilities and supporting infrastructure are severely scarce, the perceived effectiveness of small subsidies in terms of indoor containers and garbage bags for promoting waste separation would be fairly limited and the small subsidies would be considered as controlling rather than acknowledging. Thus, the subsidies should include not only indoor containers and garbage bags, but also adequate and convenient sorting facilities and supporting infrastructure. Last but not least, while regulatory sanctions and external rewards are widely used policy instruments across countries, public information and education campaigns deserve equal attention and may be more preferable for the general public. In addition to instill a sense of social responsibility, public spiritedness and social norms of cooperation, well designed and implemented campaigns can also help shape public preferences, habits, and behaviors upon waste management.

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