How much does my garbage really cost? Evidence from French communities

Amandine Gnonlonfin[1], Yusuf Kocoglu[2]

Abstract

Using original data from French communities, this paper investigates the effects of the Pay As You Throw (PAYT) mechanism on the demand for Municipal Solid Waste (MSW) services by differentiating the effect of the non-zero marginal price from the effect of the cost information. Empirical strategy allows for testing of the preventive and substitution effects of PAYT on MSW quantity and management costs. We find strong evidence in favor of both the preventive and substitution effects of the PAYT and its cost effectiveness. Compared to non-PAYT communities, communities with PAYT have a lower quantity of total waste collected, lower quantity of unsorted waste for disposal and higher quantity of separated waste for recycling. The cost information supports the preventive effect whilst the non-zero marginal price supports the substitution effect. The per capita waste disposal fee in PAYT communities is on average 20 euros lower. Furthermore, results indicate that the schema of the PAYT does matter: the more refined the marginal pricing of waste is, the greater the individual response. The effectiveness of the weight-based schema is greater than the pickup-based schema, which is greater than the volume-based schema.

Key words: garbage pricing, user fee, effectiveness, non-pecuniary preferences, intrinsic motivation, pecuniary preferences.

JEL: D10, D62, H23, O18, O53

[1] Université de Nice Sophia, Email : amandine.gnonlonfin@unice.fr; mail : Immeuble Nice Premium, Bâtiment B 4ème étage, 61-63 Avenue Simone VEIL – 06200 Nice
[2] Université de Toulon (LEAD/LIA CNRS), Email : kocoglu@univ-tln.fr.

Introduction

Many countries have been challenged by the increase in Municipal Solid Waste (MSW) and its management cost. The garbage pricing program well-known as "Pay As You Throw" (PAYT), is an economic tool designed to deal with this challenge. PAYT policies allows municipalities to charge households in relation to the waste accumulated. Essentially, the principle refers to pecuniary preferences of households by changing the marginal price from zero, which is the case in flat-rate pricing. This encourages households to firstly generate less waste and secondly increase the share of recycling. These phenomena illustrate the preventive effect and the substitution effect respectively, as predicted by theoretical literature (for example see Fullerton & Kinnaman, 1995; Choe & Fraser, 1999; Shinkuma, 2003; Kinnaman, 2010; Ino, 2011).

However, the objective for municipalities is not only to decrease waste generation; they are also seeking to reduce waste management costs. As a result, municipalities (as well as households) expect more than preventive and substitution effects from PAYT programs; they also expect it to be cost-effective. This effect is actually implicit. On one hand, the preventive and the substitution effects lead to a decrease in waste collection and disposal costs with an increase in revenue from recycled materials. On the other hand, the implementation of PAYT policies requires administration costs in addition to initial investments to adapt collection equipment or containers for measuring waste. Administration costs arise from monitoring to prevent households from illegal dumping, billing costs, and providing customer services for households. Indeed, Kinnaman (2006) estimates that increasing the curbside price of garbage from zero to 0.85$ eliminates a deadweight loss of 0.25$ per household per week, or 13.3$ per year. However, he highlights that before each household can enjoy that cost-offset free lunch, the costs of implementing and administering the unit-based curbside pricing program must be deducted from the benefits. The cost-effectiveness of PAYT programs is not obvious, especially insofar as there are economies of scale in waste management (Bohm et al., 2010; Bel & Fageda, 2010).

Empirical evidence for the preventive and substitution effects of PAYT programs is well-documented. Kinnaman (2006) reports that empirical studies over the period 1996-2004 estimated the elasticity of MSW demand to vary from -0.01 to -1.1 depending on the type of

PAYT program.[3] More recent studies across OECD countries confirm households' responsiveness to PAYT programs (for example, Allers & Hoeben, 2010; Huang et al., 2011; Usui & Takeuchi, 2014; Bucciol et al., 2015; Carattini, Baranzini, & Lalive, 2018). However, the literature provides little insight regarding the cost-effectiveness of PAYT programs, which leaves some authors skeptical. Kinnaman (2006) asserts that the net benefit of PAYT programs, after considering induced costs, is a few dollars per household per year, or even negative. Allers & Hoeben (2010) also roughly estimate that the administration costs of PAYT programs are large and can offset its welfare gains. Bohm et al. (2010) and Dijkgraaf & Gradus (2014) analyze PAYT cost-effectiveness by studying different cost functions of waste management in cross-session and panel data analysis, respectively. Bohm et al. (2010) examine a sample of municipalities in the USA and show that the effect of PAYT policies on waste collection and disposal costs is not significant. However, Dijkgraaf & Gradus (2014) show that PAYT policies significantly reduce waste management costs for Dutch municipalities. The gap between the empirical studies examining the preventive and substitution effects of PAYT and those evaluating its cost-effectiveness is somewhat puzzling. This is not helpful in terms of public support and may cause the implementation of PAYT policies to be politically challenging in some settings. For example, Kinnaman & Fullerton (2000) argue that community officials in the USA first calculate the optimal price to charge based on the trade-off between benefits and costs at the margin of PAYT implementation. If this optimal price is negative, a PAYT policy is not implemented. Gnonlonfin & Kocoglu (2018) demonstrate that costs and benefits of PAYT implementation are balanced in local communities in France. Carattini, Baranzini, & Lalive (2018) analyze the political aspects of the implementation of PAYT policies by studying the population's perception regarding PAYT programs' effectiveness, fairness, and political acceptability. The authors find that inhabitants in the canton of Vaud in western Switzerland believe that a PAYT program would not be effective and is unfair.

In addition, some authors show that the demand for MSW management, especially the demand for recycling, is subject to non-pecuniary preferences (Brekke et al., 2010; Viscusi et al., 2011; Abbott et al., 2013; Cecere et al., 2014; Miliute-Plepiene et al., 2016). These authors seek to explain individual's pro-environmental behavior as products of the the warm glow, social/moral norms, and altruism phenomena. Viscusi et al. (2011) define the warm

[3] The three types of PAYT programs considered in this survey are the bag-and-tag, weight-based, and collection of cans.

glow as the utility that individuals derive from taking pro-environmental actions. This effect is illustrated by the willingness to pay for recycling (Kinnaman, 2006) and duty-orientation (Brekke et al., 2010). Hage et al. (2009) define social norms as informal rules requiring that one should act in a given way in a given situation, exemplified by peer pressure (Abbott et al., 2013) or external norms for acceptable behavior (Viscusi et al., 2011). Kinnaman (2005) represents the utility of the household as a negative function of garbage contribution. The household suffers disutility because of its endowed sense of civic duty, to avoid the perception of harming the environment, or in accordance with a social norm. As a result, the demand for recycling, even in the absence of economic incentives, is not null.

The existence of non-pecuniary preferences makes it possible to utilize information-based techniques to promote waste prevention and recycling. Trends in energy and water use emphasize that household behavior can be influenced by promoting ecological information,[4] technical information[5] and behavioral information[6] (Schultz et al., 2007; Allcott, 2011; Costa & Kahn, 2013; Ferraro & Price, 2013; Andor & Fels, 2018). Kirakozian (2016) proposes a survey on information-based interventions, referring to behavioral instruments including nudges, personal and social norms, and social pressure. In this regard, the question is whether cost information can also result in a household's pro-environmental behavior. For example, cost information can consist of answering the question: How much does the MSW management cost? Contrary to ecological information, technical information and behavioral information, cost information is a monetary indicator, but the marginal price of the MSW still equals zero for the household. Hence, there are no pecuniary rewards for adopting pro-environmental behavior. Due to non-pecuniary preferences, we postulate that cost information can influence household demand for MSW management. In other words, knowing the actual cost of MSW may be sufficient to induce a household to undertake costly actions aimed at waste reduction and recycling. However, the fact remains that the non-zero marginal price of waste and cost information are closely connected. In these conditions, the effects of a PAYT program are composed of (1) effects of non-zero marginal price induced by pecuniary preferences and (2) effects of cost information induced by non-pecuniary preferences.

This paper contributes to empirical literature on the effectiveness of PAYT policies in three ways. It firstly proposes to investigate the preventive and substitution effects of PAYT on

[4] The "Why" of adopting pro-environmental behaviors.
[5] Advice or "Which ways" effective pro-environmental behaviors are adopted (including labeling).
[6] The "How much" variable, for example, individual consumption, average consumption in neighborhood, or standard consumption.

MSW management demand and its cost-effectiveness. Secondly, it differentiates the effect of the non-zero marginal price driven by pecuniary preferences and the effect of cost information driven by non-pecuniary preferences in the prevention of waste production and recycling and in the reduction of waste management costs. Thirdly, it examines the interaction between the effect of the non-zero marginal price and the effect of cost information. To the best of our knowledge, this paper is the first to differentiate the effects of PAYT and emphasize the role of cost information in waste prevention, recycling, and cost reduction. The French MSW funding system provides a natural experiment and makes these analyses possible. We use community-level data in a cross-sectional analysis to estimate marginal effects of the non-zero marginal price and the cost information respectively on the per capita quantity of unsorted waste collected, the per capita quantity of separated waste collected, the per capita quantity of occasional waste collected, and on the per capita waste disposal fee. We use an interaction variable to examine the interaction between the non-zero marginal price and the cost information, and we consider the potential endogeneity of PAYT adoption.

Our analysis yields several interesting results. We find strong evidence in favor of both the preventive and substitution effects of PAYT and its cost effectiveness. The per capita quantity of total waste collected in PAYT communities is lower than in non-PAYT communities by 22 kg a year on average. This confirms the preventive effect of PAYT, which is due to the cost information. The per capita quantity of unsorted waste for disposal in PAYT communities is on average 56 kg per year lower than non-PAYT communities, and the per capita quantity of separated waste for recycling is 22 kg higher on average. This confirms the substitution effect of PAYT, which is due to the non-zero marginal price. The per capita waste disposal fee in PAYT communities is lower than in non-PAYT communities by 20 euros per year on average, which confirms the cost effectiveness of PAYT programs. Furthermore, results confirm the crowding-in effect. The non-zero marginal price and the cost information are compatible without additional effects on waste prevention and recycling. PAYT relies on both pecuniary preferences and non-pecuniary preferences to be effective. Pecuniary preferences support the PAYT substitution effect whilst non-pecuniary preferences support the PAYT preventive effect. Savings from the preventive and substitution effects outweigh the implementation costs of PAYT policies. This confirms its cost effectiveness.

The following section presents the institutional context of MSW management financing in France. Section 2 presents data and econometric strategy. Section 3 and 4 present results respectively for MSW quantity effects and for the cost effectiveness of PAYT programs.

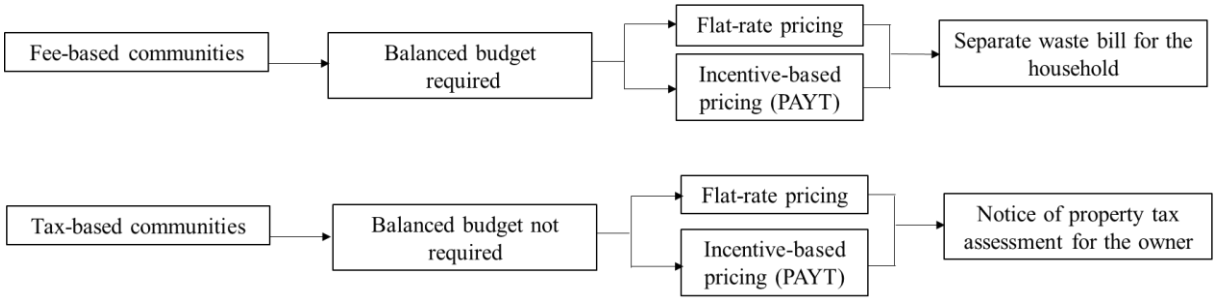
Implications for French policies regarding MSW management financing are suggested in the conclusion in Section 5.

1. How much do Municipal Solid Waste services cost? Natural experiment in French communities.

As in most countries around the world, French municipalities are responsible for household solid waste management (hereafter MSW services). MSW services include waste collection, recycling, and disposal. Municipalities can provide services independently or in intercommunal associations called "Établissement Public de Coopération Intercommunale" (EPCI) or Syndicate. We use the generic term "communities" to refer to both municipalities and intercommunal associations. By law, communities are required to fund MSW services through incentive-based (PAYT) or flat-rate pricing. The PAYT allows communities to charge households based on the weight of waste, the volume of waste, and the collection frequency.

The French regulatory framework of waste funding consists of two systems: the tax-based system and the fee-based system (Figure 1). The tax-based system considers MSW services a public utility; thus, households in a tax-based community are not billed separately for MSW services. Further, tax-based communities are not required to take into account MSW services for budget balancing, except in the case of a community opting to legally separate MSW services from the provision of other public utilities. Thus, the total amount of tax collected for MSW services can be equal to or different from the actual cost of the services. The tax is specified in property-tax assessment notices addressed to the owner who may, in turn, bill the tenant separately or include the tax in the rent payment. Whilst in the fee-system, MSW services are considered as commercial and industrial services and this system requires a balanced budget, and all households in a fee-system community (hereafter fee based community) receive a separate bill for MSW services. Both tax-based and fee-based communities can transition from flat-rate pricing to PAYT policies, which does not change any procedures for MSW services. As expected, the marginal price is thereafter different from zero. Nonetheless, fee-based communities are still legally required to balance the budget and provide households with a separate bill for MSW services, while tax-based communities face no such requirements.

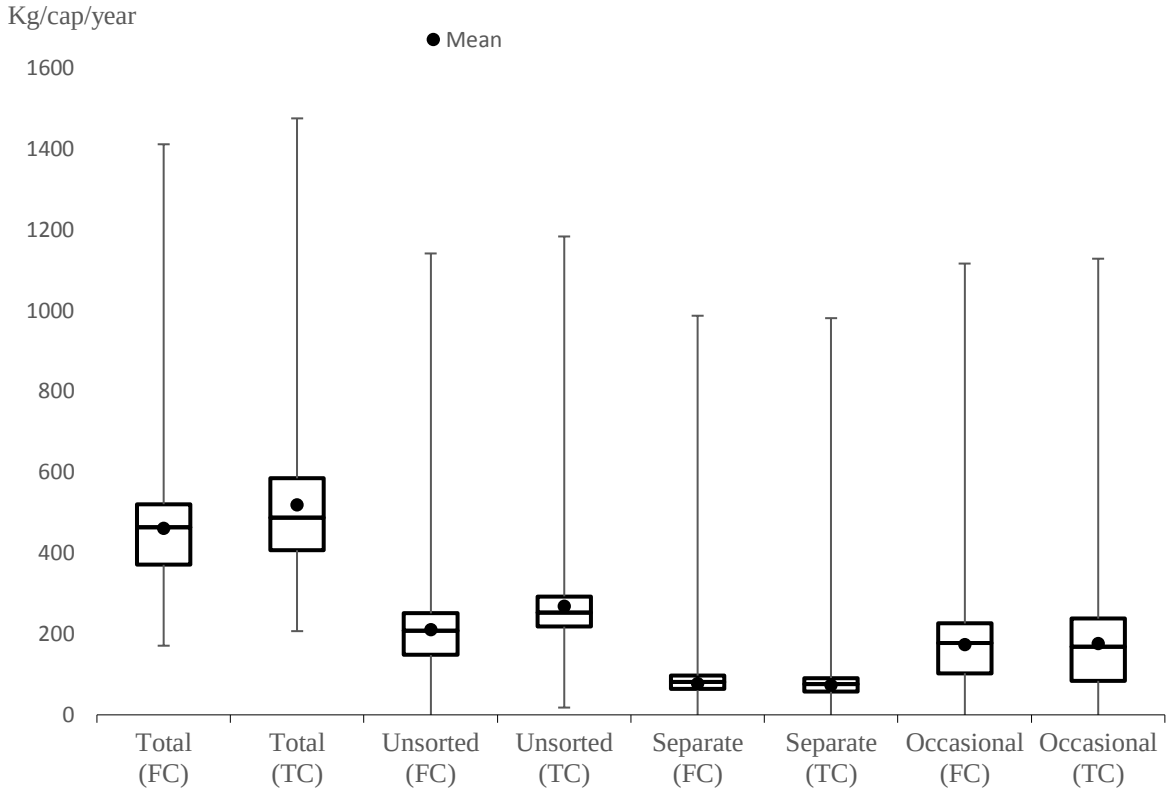
Fig. 1 : French MSW funding system



The French MSW funding system provides an interesting natural experiment and allows for the evaluation of the effect of cost information on the demand for MSW services. We assume that households in fee-based communities have accurate information on the actual cost of waste in their community, due to the requirement of a balanced budget and the billing of households for MSW services. They can answer the question: "How much do MSW services cost?" This is not the case for households in tax-based communities for several reasons. First, households in tax-based communities know that the total amount of tax can differ from the actual cost of MSW services. Second, households do not receive a separate bill; instead, owners receive a notice with the property tax assessment. Even for the owner, this cannot be considered a bill for MSW services because the tax amount is appended and therefore is quite simply secondary information. Third, owners generally incorporate the tax into the rental price. Thus, it is easier for a household in a fee-based community to locate information on the actual cost of MSW services in comparison with a household in a tax-based community. A separate bill informs households of the actual cost of MSW services. As a result, households in fee-based communities with flat-rate pricing are exposed to the cost information; households in fee-based communities with PAYT policies are exposed to both the cost information and the non-zero marginal price. Households in tax-based communities with PAYT policies are only exposed to the non-zero marginal price.

Since the 1970s, French communities have been able to deliberately choose to fund MSW services using the tax-based or the fee-based system. In 2013, 67% of communities funded their MSW services under the tax-based system (Observatoire des finances locales, 2014). The average demand for MSW services (total collection) in fee-based communities is about 60kg/cap/year lower than the average demand in tax-based communities (Table 1). It is noteworthy that this difference is driven by the demand for unsorted collection, which is largely destined for landfills and incineration.

Fig. 2 : MSW demand by funding system (2013)



Note: FC: Fee-based communities, TC: Tax-based communities, Total: Total collection, Unsorted: Unsorted collection, Separate: Separate collection, Occasional: Occasional collection.

Source: Sinoe/ADEME

The average demand for separate and occasional collections, that are typically for recycling, is similar in both tax and fee-based communities. Separate collection includes packaging materials, glass, and food waste. Occasional collection refers to irregular collection and the collection of bulky waste, garden waste, hazardous waste and electronic waste at recycling centers. Does the cost information influence the demand for MSW services in French communities?

We assume that non-pecuniary preferences lead households in fee-based communities to undertake costly actions to lower their demand for MSW services. Our goal is to distinguish the effects of the cost information from the effects of the non-zero marginal price and to test if the latter has a crowding out effect (vs crowding in) on the former. We then compare the MSW management of four groups of communities as described in Table 1: Tax-based system only, tax-based system and PAYT, fee-based system only, and fee-based system and PAYT.

Table 1 : Average MSW management demand per capita in 2013

Funding system	Total MSW(kg/cap/year)	Type of collection (kg/cap/year)		
		Unsorted	Separated	Occasional
Fee-based communities	460	209	77	174
PAYT (Fee-based PAYT)	421	132	99	190
Non PAYT (Fee-based system only)	472	232	71	169
Tax-based communities	520	270	74	176
PAYT (Tax-based PAYT)	455	171	96	188
Non PAYT (Tax-based system only)	521	271	73	176

Source: Sinoe/ADEME

In the following sections, we evaluate the preventive and the substitution effects of PAYT on the demand for MSW services and its cost effectiveness by using an original institutional dataset consisting of 1,340 communities in France. We first describe this dataset, which encompasses about 80% of the total population of France. We also describe the institutional context of MSW management, highlighting the national policies that incentivize communities to utilize sustainable MSW management, and we describe the empirical strategy (Section 2).

2. Data and econometric strategy

We propose to investigate, using community data, the effects of PAYT on the demand for MSW services by differentiating the effect of the non-zero marginal price from the effect of the cost information. From Kinnaman and Fullerton's (2000) model, the demand for MSW services is a function of household income, demographic characteristics, and the marginal price of waste disposal and waste recycling. In line with previous studies using community data, we estimate the household demand as:

$$q_i = \beta_0 + \beta_1 PAYT_i + \beta_2 FS_i + \beta_3 PAYT_i * FS_i + \beta_4 X_i + \varepsilon_i, \qquad (1)$$

where q_i denotes the per capita demand for MSW services in community i; $PAYT$ is a dummy variable with a value of 1 if community i has a PAYT schema; FS is a dummy variable related to the funding system with a value of 1 for a fee-based system; the interaction term $PAYT * FS$ measures the additional effect of fee-based systems with PAYT schemas; X denotes a vector of other control variables like household income, demographic characteristics and MSW services characteristics; ε_i is the normally-distributed error term. The coefficients β_1 and β_2 represent the marginal effect of the non-zero marginal price and of the cost information respectively. Regarding the four group communities defined in Table 1, the tax-system-only schema is the reference, and β_1 measures the marginal effect of the

PAYT schema; β_2 measures the marginal effect of fee-based systems; and $\beta_1 + \beta_2 + \beta_3$ is the marginal effect of the fee-based PAYT schema. If β_3 is significant we will conclude in favor of an additional effect.

We gathered data on MSW services from the Sinoé-ADEME database and various publications of ADEME.[7] Data on the funding system derives from the French General Directorate of Public Finance (DGFiP). We utilized the most recent and complete data, which is from the year 2013. Our sample includes 1,340 communities encompassing about 82% of the French population. We use the quantity of collected waste per capita as a proxy of the demand for MSW services. The total collection represents the total demand for MSW services, which includes the demand for disposal as represented by the unsorted collection and the demand for recycling as represented by separate collection /occasional collection. Although French communities are not required to provide all three types of waste collection, they are supported by the national Extended Producer Responsibility (EPR) programs that subsidize recycling for several waste flows.

The French EPR policy was launched in 1990, and the majority of waste that ends up in separate or occasional collection is already regulated by EPR programs. In 2013, all households had access to curbside collection for glass and packaging materials at the least. Further, communities were encouraged to recycle due to the national tax on waste disposal called "la Taxe Générale sur les activités polluantes- DMA". Since 2000, communities have paid this tax based on the quantity of waste they incinerate, landfill and dump. In 2013, the tax rate was 100€/ton of waste landfilled or dumped and 10-30€/ton of waste incinerated. The EPR policy and the national tax on waste disposal are exogenous and change the relative price of both recycling and disposal for all communities. As our estimations employ cross-section data, we cannot evaluate the effects of these national policies on our outcome variables.

The total collection equals the sum of unsorted, separate, and occasional collections. We assume that the three types of collection are substitutes. This means that illegal dumping, referring to any misconduct in waste disposal[8], is insignificant in communities that implement PAYT policies. The reason for this assumption is twofold. First, communities report that they observe some inappropriate waste disposal at the beginning of implementation, but this decreases quickly over time with effective control. Second, in all communities, PAYT

[7] ADEME is the French national agency responsible for environmental issues. Once every two years, ADEME surveys a representative sample of communities on waste management service.
[8] For example, waste tourism, waste disposal on roadsides or at common places, or waste burning.

programs include a fixed rate (up to 70% of the fee) for minimum service that may be a minimum number of weight, volume or number of collections. Further, PAYT usually generates positive marginal price for unsorted collection while separate and occasional collections are still free.[9] As a result, we can confirm the preventive effect of PAYT if the coefficient β_* in Equation (1) is negative for the per capita total collection (hereafter total collection model). We can confirm the substitution effect if the coefficient β_* is jointly negative for the per capita quantity of unsorted collection (hereafter unsorted collection model) and positive for the per capita separate or occasional collection (hereafter separate collection model/ occasional collection model).

The adoption of PAYT policies is endogenous, as the decision to implement it is at the communities' own discretion. Beginning with only three communities in the early 2000s, 150 communities (3.6 million inhabitants) had adopted the PAYT as of January 1, 2014 (Table 2). However, due to incomplete data, our sample is composed of 102 representative communities including 2.5 million inhabitants.[10] It must be emphasized that the majority of these communities (about 78%) adopted the PAYT after the year 2009. Indeed, since 2009, a national program has subsidized communities for PAYT adoption. The "Fonds Déchets" of ADEME helps finance, up to a ceiling of 55% and 70%, the cost of feasibility studies and preliminary investments, respectively. In addition, communities receive, under certain conditions, a subsidy per inhabitant for the first year of PAYT adoption. Our strategy for controlling the endogeneity of PAYT adoption is the use of control variables.[11]

As we mentioned in the previous section, communities are also free to choose the funding system. This choice is correlated with demographic characteristics and other institutional choices.[12] Typically, rural communities choose the fee-based system, and urban communities choose the tax-based system. Furthermore, the adoption of PAYT policies is correlated with

[9] Only 14% of communities with a PAYT program charge a marginal price beyond a minimum separate collection or collection at recycling centers.

[10] Including communities that adopted PAYT prior to January 1, 2014 in our sample, does not matter. To communicate with and inform households, communities commonly tested the PAYT schema for six to twelve months before official implementation. During the testing period, households still paid flat-rate prices according to the funding system of their community. As a result, the change in household demand for the waste management service began in the year 2013.

[11] For the purpose of a sensibility analysis, we have alternatively used the procedure presented by Angrist (2001), and results are consistent.

[12] According to the demographic characteristics, communities are required to provide a minimum level of waste services, specifically the number of collections per week.

the choice of funding system.[13] Communities with PAYT are also more likely to upgrade the level of waste collection in order to control for illegal dumping and minimize the cost of MSW services. For example, simultaneous with PAYT adoption, communities may enhance the separate collection schema for more effectiveness by increasing the number of material flows included in the separate collection, increasing the number of recycling centers, or by participating in national pilot programs to encourage waste reduction. Consequently, in addition to demographic characteristics, we consider a number of observed variables related to institutional characteristics, waste prevention, and separate collection characteristics. Most of these variables are derived directly from the literature (for example, see Dijkgraaf & Gradus, 2014) and are used as control variables. Moreover, we include the waste disposal fee per capita as an ultimate control variable. This is the tax/fee collected per capita for waste management service and acts as a proxy for other unobservable factors that may influence the adoption of PAYT. The role of all control variables in the estimations is to reduce the bias of omitted variables and to control for the endogeneity of the PAYT variable. Table 3 presents a summary of statistics for each variable, and Table A1 in the appendix defines each variable.

Table 2 : PAYT adoption over the period 1997-2014

5-year period	Prior to 1999	2000-2004	2005-2009	2010-2014
New communities	3	5	24	118
Aggregate number	3	8	32	150

Source: ADEME (2014)

Above all, we consider the fact that PAYT adoption is not random, but is motivated by the level of environmental activism of the citizens. As discussed by Dijkgraaf and Gradus (2004, 2009), households in a community with PAYT programs are more concerned with environmental problems due to waste than households in a community with flat-rate pricing. As such, the demand for MSW services in communities of the former is already lower than the demand in the latter communities. Failure to take this into account can lead to an overestimation of the effect of PAYT policies. The level of environmental activism is correlated with the political affiliation of the population (Dijkgraaf & Gradus, 2004). In a democratic system, citizens with a high level of environmental activism tend to vote for the

[13] Until 2010, French legislation did not allow for incentive pricing under the tax-based system. As of January 1, 2014, only three communities had adopted PAYT policies under the tax-based system. However, there are tax-based communities that adopted both a PAYT program and the fee-based system on January 1, 2014. Due to a lag between the official adoption of the PAYT program and the fee-based system, households in these communities were informed in 2013 that the PAYT program and fee-based system would be effective beginning January 1, 2014, but they effectively paid the flat rate under the tax-based system in 2013. For this reason, these communities are considered tax-based communities with a PAYT program. In total, 21% of communities with a PAYT program in our sample are considered tax-based communities.

most eco-conscious political party or at least a political party with pro-environmental projects. At the local governance level, politicians must initiate a pro-environmental policy to satisfy their electorate. The adoption of PAYT may be an operational measure of this trend.

Regarding Figure A.1 in the appendix, the non-random spatial distribution of communities with a PAYT schema is noteworthy. We assume that this distribution is correlated with a high level of environmental activism. Therefore, we consider the distribution rate, defined as the share of the population involved in PAYT programs at the French regional level,[14] as a proxy for the level of environmental activism. This variable ranges from 0 to 1, and the higher its value, the greater the level of environmental activism. A zero value implies that the level of environmental activism in the French region is too low to lead local governments to adopt a PAYT program. We expect that this variable reduces the endogeneity bias by controlling for the difference in the initial demand for waste management services between communities with PAYT and communities with flat-rate pricing.

Having described the institutional context of MSW management funding and the econometric strategy, we present estimations of the demand for MSW management services in the next section.

[14] French regions are the largest administrative unit in France and are further subdivided into departments. In 2013, regions had no jurisdiction over municipal waste management, while departments were responsible for planning the prevention and management of non-hazardous waste. Thus, the organization of the regional administrative level guarantees that the distribution of the population implicated by PAYT policies is not a result of any regional policies.

Table 3: Descriptive statistics

Variables	Obs.	Mean	S.D.	Min.	Max.
Outcomes					
Total collection (kg per capita)	1340	504	184	40	2013
Unsorted collection (kg per capita)	1340	253	108	0	1330
Separate collection (kg per capita)	1340	75	36	0	310
Occasional collection (kg per capita)	1340	176	129	0	1727
Waste disposal fee (€ per capita)	1340	92	58	0.003	685
Funding characteristics					
PAYT	1340	0.08	0.26	0	1
Tax-based PAYT	1340	0.02	0.13	0	1
Fee-based PAYT	1340	0.06	0.24	0	1
Volume-based	1340	0.01	0.09	0	1
Weight-based	1340	0.02	0.13	0	1
Pickup-based	1340	0.05	0.22	0	1
Tax-based system	1340	0.73	0.44	0	1
Fee-based system	1340	0.27	0.44	0	1
Population characteristics					
Income (€1000)	1095	20.42	3.16	12.87	43.08
Urban	1340	0.26	0.44	0	1
Tourism	1340	0.12	0.33	0	1
Rural	1340	0.62	0.49	0	1
Control variables					
Environmental activism	1340	0.06	0.10	0	0.45
Private	1340	0.54	0.50	0	1
Disposal-recycling subcontracting	1340	0.73	0.44	0	1
Collection subcontracting	1340	0.03	0.17	0	1
Township	1340	0.10	0.31	0	1
Syndicate	1340	0.17	0.33	0	1
EPCI	1340	0.72	0.49	0	1
Community size	1340	23	36	1	592
Prevention programs	1340	0.31	0.46	0	1
Home composting	1340	0.56	0.50	0	1
Separated flux (number of)	1340	4	2	0	8
Recycling center (number of)	1340	2	3	0	32
Multi-material schema	1241	0.50	0.50	0	1
Packaging-paper schema	1241	0.26	0.44	0	1
Fibrous schema	1241	0.09	0.29	0	1
Mix of schema	1340	0.02	0.12	0	1
Other schema	1241	0.13	0.34	0	1

Source: Sinoé, DGFiP, ADEME (2014)

3. Preventive and substitution effects of PAYT

Following the empirical strategy described in the previous section, we estimate Equation (1) with the Ordinary Least Squares (OLS) method with coefficients representing the marginal effects. In order to check the robustness and the consequences of the limited number of observations for some variables, we first estimate Equation (1) considering only the funding system. In our second and third steps, we examine the other funding variables and control variables, respectively. Table 5 concisely presents the third step in estimating the total collection model to evaluate the preventive effect and the unsorted, separate and occasional

collection models for the substitution effect. Stepwise results for these models are presented in the appendix (Table A.2). We perform the usual multicollinearity and heteroscedasticity tests[15]. The results in Table 5 demonstrate the robustness of our estimates, and we solely focus on the coefficients of the funding variables in the third step.[16] Furthermore, we have checked the endogeneity of the variable PAYT with two-stage least square models by employing the procedure presented by Angrist (2001). The endogeneity test is not significant, and the results are quite similar to the results given by the OLS models.[17]

3.1. Non-zero marginal price effect, cost information effect, and crowding effect

We reiterate that a primary objective of this paper is to investigate the preventive effect and the substitution effect of PAYT by distinguishing the effect of the non-zero marginal price from that of the cost information. As stated in Section 1, the waste management funding system allows us to identify the four types of communities displayed in Table 4: those with households subjected to neither the non-zero marginal price nor having the cost information of waste, those with households subjected to the non-zero marginal price of waste, those with households having the cost information of waste, and those with households subjected to the non-zero marginal price and having the cost information of waste.

Table 4 : Funding system and PAYT

	Tax-based communities	Fee-based communities	Total
PAYT	16	86	102
Non-PAYT	962	276	1238
Total	978	362	1340

Source: Sinoé, DGFiP, ADEME (2014)

Table 5 presents the results estimated by Equation 1; of note, the reference group is tax-based communities with no PAYT schema. Firstly, the results confirm the cost information effect. The coefficient of the Fee-based system variable, measuring the "Fee-based system only" marginal effect, is negative and significant in the total collection model as well as in the unsorted collection model. The average total MSW collected per capita in fee-based communities, via the unsorted collection, is then lower than the average total MSW collected in the reference group. This confirms the preventive effect of the cost information, which is

[15] The Breuch-Pagan test indicates that there is cross-sectional heteroscedasticity; the robust standard errors are used to correct this issue.
[16] The variables for demographic characteristics have the expected sign and speak for themselves. Other independent variables are included to control for the bias of omitted variables.
[17] Results of 2SLS models are available on request.

driven by non-pecuniary household preferences. In fee-based communities where households are billed for waste management services and are considered to know the actual cost, the demand for the total collection is lower by 23 kg/cap/year. That is, for a community of 50,000 inhabitants, the reduction of MSW collection would be around 1,000 tons per year. Since the average collection of MSW is 520 kg/cap/year for tax-based communities, the fee-based system would reduce the total MSW collection by 4.2%. This is due to a reduction of the demand for unsorted collection and supports our hypothesis that non-pecuniary preferences lead households to undertake costly actions aiming to prevent waste production. However, the "fee-based system only" marginal effect is not significant in the separate collection model or the occasional collection model, indicating that the cost information does not affect the demand for recycling. This phenomenon confirms the significant role of intrinsic motivation in waste prevention and the insignificant role of external motivation in recycling. Indeed, Cecere et al. (2014) differentiate the roles of intrinsic and extrinsic motivation. They emphasize that intrinsic motivation, which includes the warm-glow payoff, the joy of giving, and altruistic preferences, influences waste prevention, while extrinsic motivation such as social norms influences waste recycling. In contrast to those who are extrinsically motivated, agents driven by intrinsic motivation do not expect any external rewards such as pecuniary rewards, a boost to social reputation, or a better self-image. Actions taken by households to prevent waste production are mainly unobservable by peers, while efforts to recycle are often visible. Previous empirical studies confirm a significant effect of the social/moral norms that influence self-image or social acceptance, on recycling behavior.

Secondly, our results confirm the effect of the non-zero marginal price. The estimated coefficient of the PAYT variable measuring the "tax-based PAYT" marginal effect is significant and negative in the unsorted collection model yet significant and positive in the separated collection model. Introducing a PAYT schema in tax-based communities increases the average separate collection per capita and decreases the average unsorted collection per capita. This does not result in a significant decrease in the average total collection per capita. Indeed, in communities that adopt the tax-based system and implement a PAYT schema, the unsorted collection is 56 kg/year lower per capita and the separated collection is 22 kg/year higher per capita in comparison with communities that solely adopt the tax-based system. As the average collection of separated waste is about 73 kg/year per capita in tax communities with no PAYT policies, this result implies a 30% increase in separated waste collection with PAYT systems.

Table 5 : The preventive effect and the substitution effect of PAYT

	(1) Total collection	(2) Unsorted collection	(3) Separate collection	(4) Occasional collection
Funding variables				
PAYT	-42.52	-56.46***	22.06**	-8.13
	(32.02)	(14.31)	(8.56)	(27.51)
Fee-based system	-22.93*	-21.83***	1.97	-3.07
	(13.89)	(5.91)	(2.49)	(11.46)
PAYT*Fee-based system	4.19	1.32	-10.33	13.20
	(35.95)	(15.87)	(9.12)	(30.80)
Tax-based system	Ref	Ref	Ref	Ref
Demographic variables				
Income	0.98	-2.50**	0.89**	2.60**
	(1.51)	(0.80)	(0.29)	(1.15)
Urban	-57.10***	30.53***	-18.31***	-69.31***
	(13.26)	(5.80)	(2.43)	(10.98)
Tourism	125.50***	98.20***	10.95**	16.35
	(24.07)	(14.16)	(5.05)	(16.41)
Rural	Ref	Ref	Ref	Ref
Control variables				
Environmental activism	2.25	-106.92***	52.09***	57.09
	(48.76)	(17.75)	(9.35)	(45.21)
Private	-12.53	-0.37	-3.09*	-9.07
	(10.44)	(4.27)	(1.82)	(9.09)
Disposal-recycling subcontracting	-23.18**	-11.99*	-1.76	-9.43
	(11.56)	(6.24)	(1.99)	(8.36)
Collection subcontracting	-22.66	-38.73**	13.42	2.65
	(62.39)	(12.95)	(33.12)	(36.33)
Community size	-0.22	0.21*	0.18***	-0.60**
	(0.24)	(0.12)	(0.05)	(0.20)
Prevention programs	-0.61	-11.54**	4.27**	6.66
	(11.20)	(4.13)	(1.95)	(9.18)
Home composting	-17.40	-14.02**	-3.58**	0.21
	(10.61)	(4.89)	(1.76)	(8.89)
Separated flux	3.82	0.06	1.57**	2.19
	(4.09)	(2.05)	(0.72)	(3.33)
Recycling center	10.69***	-0.69	0.52	10.86***
	(2.44)	(1.13)	(0.41)	(2.05)
Waste disposal fee	1.31***	0.89***	0.13***	0.30**
	(0.22)	(0.14)	(0.04)	(0.12)
Multi-materials schema	-26.73*	-6.39	2.41	-22.74*
	(14.66)	(6.55)	(2.70)	(12.09)
Packaging-paper schema	-11.61	6.01	-6.60**	-11.02
	(16.44)	(7.01)	(2.82)	(14.48)
Fibrous schema	-14.34	-14.05	-4.26	3.97
	(18.51)	(9.24)	(3.11)	(15.12)
Mix of schema	-56.97**	-36.11**	8.38*	-29.23
	(25.47)	(11.84)	(4.67)	(20.10)
Other schema	Ref	Ref	Ref	Ref
Constant	393.30***	235.55***	41.62***	116.13***
	(38.82)	(21.86)	(7.39)	(28.74)
N	1006.00	1006.00	1006.00	1006.00
R^2	0.37	0.58	0.25	0.13
R^2 adjusted	0.36	0.58	0.24	0.11
Wu-Hausman test of endogeneity (p-value)	0.31	0.53	0.72	0.34

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$. Dependent variables: (1) Total collection per capita, (2) unsorted collection per capita, (3) separate collection per capita and (4) occasional collection per capita.

Households in tax-based communities with a PAYT schema do not receive a separate bill for MSW services, and for the reasons outlined in Section 1, they are considered to be subject only to the non-zero marginal price. This result demonstrates that the pecuniary preferences of households lead them to replace their demand for unsorted collection with a demand for separated collection without undertaking costly actions that significantly reduce the demand for total collection. As stated in Section 2, the non-zero marginal price resulting from the implementation of PAYT schemas is related to unsorted collection in most communities. This leads to increased sorting efforts by households due to a relative decrease in the price of separate collection.

Thirdly, the results confirm both the substitution effect and the preventive effect of PAYT in fee-based communities. In keeping demographic and control variables constant, the combination of the Fee-based system and PAYT, which is the effect of the non-zero marginal price and the cost information, leads households to reduce their demand for total collection (on average 23 kg/cap/year) by decreasing unsorted collection (on average 78 kg/cap/year) and increasing separate collection (on average 22 kg/cap/year). The decrease in unsorted collection is greater than the increase in separate collection; thus, the cross effect is a decrease in total collection. The coefficient of the interaction variable Fee*PAYT is not significant for any of the four model in Table 5. This result indicates that there is not a positive or negative additional effect when combining the Fee-based system and PAYT schemas; each public choice demonstrates a separate effect. These two effects taken together lead to a significant decrease in MSW collection, but they do not reinforce each other. On one hand, purely pecuniary preferences drive households to sort their waste and increase their demand for separate collection at the expense of unsorted collection. On the other hand, purely non-pecuniary preferences drive households to prevent waste production altogether. The cost information effect does not crowd-out the non-zero marginal effect price because waste reduction is mainly associated with intrinsic motivation (Cecere, Mancinelli, & Mazzanti, 2014). This result is in line with previous studies showing compatibility between the effect of intrinsic motivation on waste prevention with recycling policies or incentive-based pricing (Hage et al., 2009; Abbott et al., 2013; Miliute-Plepiene et al., 2016).

Lastly, the results confirm the environmental activism hypothesis with a significant coefficient in the unsorted and sorted collection models, but significance is not present in the total or occasional collection models. This indicates that a high level of environmental

activism is characterized by a low demand for unsorted collection and a high demand for separate collection. The demand for total collection does not significantly differ from the average demand. Results show that PAYT adoption by French communities is positively correlated with the sorting efforts of households.

In conclusion, the results in this section show that PAYT satisfies both pecuniary and non-pecuniary preferences, especially in terms of intrinsic motivation. PAYT policies, via the non-zero marginal price and the cost information, activate purely economic and behavioral mechanisms to effectively reduce the demand for waste management services. Finally, these results for French communities are in line with previous studies that evaluate the effect of PAYT on the demand for MSW (Dijkgraaf & Gradus, 2004, 2009; Sidique et al., 2010; Huang et al., 2011; Bucciol et al., 2015).

3.2. The importance of the PAYT schema

In this section, we investigate how the different PAYT schemas impact MSW collection. Communities are left to freely design their PAYT schema. The marginal price may depend on the weight, the volume, the number of collections, or a combination of these three mechanisms. Under these conditions, it was not possible to evaluate the marginal price of waste. However, we have identified three schemas to address each of the above criteria: the volume-based schema refers to communities in which the marginal price depends uniquely on the volume criterion (including bag-based); the pickup-based schema refers to communities in which the marginal price depends on both the volume and the pickup criteria, and the weight-based schema refers to communities in which the marginal price depends on the weight criteria. We consider that the weight-based schema is more refined than the pickup-based schema, which is more refined than the volume-based schema. It can be expected on theoretical grounds that the more refined the marginal pricing is, the greater the household's response is.

Table 6 demonstrates that the most popular PAYT schema is the pickup-based followed by the weight-based schema. We generate dummy variable for each PAYT schema in our database; i.e., tax system with pickup-based schema, fee system with volume-based schema, fee system with weight-based schema, fee system with pickup-based schema, fee system with no PAYT, and tax system with no PAYT.

Table 6 : PAYT schema as of January 1, 2014

Schema	Number of communities in the sample	Percentage (%) of the sample	Percentage (%) of the population
Volume-based	10	10	9
Fee system	9		
Tax system	1		
Weight-based	23	22	19
Fee system	23		
Tax system	0		
Pickup-based	69	68	72
Fee system	54		
Tax system	15		
Total PAYT	102	100	100

Source: ADEME (2014), DGFiP

Then our estimation is based on the following equation:

$$q_i = \beta_0 + \beta_1 Fee\_non\_payt_i + \beta_2 Fee\_volume\_based_i + \beta_3 Fee\_weight\_based_i + \beta_4 Fee\_pickup\_based_i + \beta_5 Tax\_pickup\_based_i + \beta_6 X_i + \varepsilon_i, \quad (2)$$

Table 7 contains the results, concisely listing only funding and demographic variables. The tax system with no PAYT continues to be the reference group. The coefficients of the funding variables represent the marginal effect of the PAYT schemas and of the cost information. Our estimations underscore that the PAYT schema has a significant impact since the effects of the non-zero marginal price are different according to the PAYT schema. The preventive and substitution effects are confirmed for the weight-based and pickup-based schemas. Introducing a weight-based schema to a fee-based system reduced the total collection by 84 kg/cap/year through an average decrease of 102 kg/cap/year in unsorted collection and an average increase of 26 kg/cap/year in the separated collection model. The pickup-based schema reduced unsorted collection by 70 kg/cap/year in fee-based systems and increased the separate collection by 8 kg/cap/year. The average decrease in total collection for the pickup-based schema is about 56 kg/cap/year. The volume-based schema appears to have a lesser effect on the demand for total waste collection. For fee-based communities that use this schema, separate collection increased by 12 kg/cap/year and unsorted collection decreased by 43 kg/cap/year. However, the decrease in total collection is not significant. As outlined in the literature, the volume-based schema can lead households to overload their bins without reducing their waste disposal (Hage & Söderholm, 2008; Dijkgraaf & Gradus, 2009; Hage et al., 2009; Dahlén & Lagerkvist, 2010). These results confirm our hypothesis that the more refined the marginal price is, the greater the household's response. Another interesting

question is whether the effectiveness of PAYT in reducing waste and increasing recycling translates into cost saving. We address this question in the following section.

Table 7 : The preventive and substitution effect of the PAYT schema on the aggregate households' demand for waste management service

	(1) Total collection	(2) Unsorted collection	(3) Separate collection	(4) Occasional collection
Funding variables				
Fee-non-PAYT	-22.76[a]	-21.66***	1.90	-3.00
	(13.91)	(5.91)	(2.49)	(11.47)
Fee-volume-based	-19.11	-42.68**	12.18**	11.39
	(48.42)	(17.55)	(4.83)	(38.54)
Fee-weight-based	-84.34***	-101.68***	25.69***	-8.35
	(21.43)	(8.16)	(4.76)	(19.29)
Fee-pickup-based	-56.56**	-70.12***	7.86**	5.70
	(20.23)	(6.58)	(3.56)	(19.88)
Tax-pickup-based	-41.78	-55.70***	21.75**	-7.83
	(32.01)	(14.34)	(8.57)	(27.51)
Tax-non-PAYT	Ref	Ref	Ref	Ref
Demographic variables				
Income	0.96	-2.51**	0.87**	2.60**
	(1.49)	(0.79)	(0.29)	(1.15)
Urban	-56.73***	30.85***	-18.38***	-69.21***
	(13.22)	(5.78)	(2.43)	(10.97)
Tourism	125.56***	98.28***	10.89**	16.39
	(24.10)	(14.17)	(5.06)	(16.43)
Rural	Ref	Ref	Ref	Ref
Constant	393.45***	235.52***	41.89***	116.03***
	(38.51)	(21.72)	(7.35)	(28.67)
N	1006.00	1006.00	1006.00	1006.00
R^2	0.37	0.59	0.26	0.13
R^2 adjusted	0.36	0.58	0.24	0.11

Standard errors in parentheses. [a] $p < 0.15$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$.
Dependent variables: (1) Total collection per capita, (2) Unsorted collection per capita, (3) Separate collection per capita and (4) Occasional collection per capita. All control variables are included in the estimate.

4. The cost-effectiveness of PAYT

This section investigates the cost-effectiveness of PAYT by distinguishing the non-zero marginal price effect from the cost information effect. We estimate the following two equations using the same empirical strategy described in Section 3, but the cost of MSW services is the new dependent variable:

$$wc_i = \beta_0 + \beta_1 PAYT_i + \beta_2 FS_i + \beta_3 PAYT_i * FS_i + \beta_4 X_i + \varepsilon_i, \quad (3)$$

$$wc_i = \beta_0 + \beta_1 Fee\_non\_payt_i + \beta_2 Fee\_volume\_based_i + \beta_3 Fee\_weight\_based_i + \beta_4 Fee\_pickup\_based_i + \beta_5 Tax\_pickup\_based_i + \beta_6 X_i + \varepsilon_i, \quad (4)$$

with wc_i representing the annual per capita tax/fee collected by community i for waste management services; all other variables are the same as in Equations (1) and (2). The coefficients β_1 and β_2 in Equation (3) represent the effect, respectively, of the non-zero marginal price and the cost information on the cost of MSW services. We can confirm the cost-effectiveness hypothesis if β_1 and β_2 are equal to zero or significantly negative. This means that the cost of waste management services is not significantly higher with the non-zero marginal price or with the cost information.

We use the waste disposal fee per capita as a proxy of the waste management cost. This represents the net cost of the subsidies of the EPR programs and the revenue from recycled materials. The average waste disposal fee in Table 3 is close to the average cost of waste management estimated by the ADEME.[18] However, our sample includes two types of communities: communities in which the amount of the collected tax/fee equals the actual net cost of waste management (fee-based communities and tax-based communities with annexed budgets) and communities in which the amount of the collected tax/fee differs from the actual net cost (lower,higher than, or even equal to), or tax-based communities without an annexed budget. We limit the sample to the former communities in order to ensure the accuracy of the waste disposal fee as a proxy of the waste management cost. We reiterate that budget balancing is required for communities that separate waste management services from the provision of other public utilities. Consequently, they must have an annexed and balanced budget for waste management services.

Columns 1 and 2 of Table 8 present the estimations[19] from Equations (3) and (4) respectively; the reference group is tax-based communities with an annexed budget.[20] Following our previous methodology, we separate the effect of the non-zero marginal price, the effect of the cost information, and the effect of the PAYT schemas on the waste disposal fee. The results indicate that all funding variables interact significantly in reducing waste management costs. On average, households in fee-based communities, including those with a PAYT schema, are charged 21€/cap/year less for MSW services than households in the reference group. Likewise, households in tax-based communities with a PAYT schema are charged

[18] The global MSW management cost is estimated at 93 €/cap/year (ADEME, Awiplan SARL, 2017)
[19] The Durbin test and the Wu-Hausman test of endogeneity do not reject the null hypothesis of exogeneity of variables (p-value= 0.51).
[20] We have performed a sensitivity analysis on the entire sample, and the results are consistent. Results are available on request.

17€/cap/year less than households in the reference group. The effect of the cost information on the waste disposal fee is slightly higher than the effect of the non-zero marginal price.

Table 8 : The cost-effectiveness of PAYT

	(1) Waste disposal fee/cap	(2) Waste disposal fee/cap
Funding variables		
PAYT	-16.67**	
	(6.61)	
Fee-based system	-21.00***	
	(5.18)	
PAYT*fee-based system	13.82*	
	(7.45)	
Tax-based system	Ref	
Fee-system-non-PAYT		-20.99***
		(5.19)
Fee-volume-based		-24.43**
		(8.43)
Fee-weight-based		-27.34***
		(5.95)
Fee-pickup-based		-21.98***
		(5.60)
Tax-pickup-based		-16.58**
		(6.64)
Tax-system-non-PAYT		Ref
Demographic variables		
Income	1.52	1.56
	(0.93)	(0.95)
Urban	9.09*	9.16*
	(5.20)	(5.23)
Tourism	84.87***	84.90***
	(12.48)	(12.52)
Rural	Ref	Ref
Control variables		
Environmental activism	-18.05	-18.88
	(12.69)	(12.82)
Private	-4.08	-4.08
	(3.88)	(3.88)
Disposal-recycling subcontracting	3.00	2.99
	(3.66)	(3.67)
Collection subcontracting	-28.96**	-28.94**
	(9.93)	(9.96)
Community size	-0.17	-0.16
	(0.12)	(0.12)
Prevention programs	-2.39	-2.48
	(4.19)	(4.21)
Home composting	-0.90	-0.92
	(3.72)	(3.73)
Separated flux	1.03	1.05
	(1.77)	(1.77)
Recycling center	1.13	1.10
	(0.78)	(0.79)
Multi-materials schema	-10.35	-10.43
	(7.15)	(7.23)
Packaging-paper schema	-10.62	-10.80
	(8.16)	(8.32)
Fibrous schema	-21.63**	-21.74**
	(7.82)	(7.91)
Mix of schema	-26.13**	-25.57**

	(11.03)	(11.02)
Other schema	Ref	Ref
Constant	79.12***	78.43***
	(17.07)	(17.13)
N	456.00	456.00
R^2	0.42	0.42
R^2 adjusted	0.40	0.39

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < .001$.

The coefficient of the interaction variable is positive and approximately equal to 14€/cap/year, which suggests that the cost-saving effect of a combined PAYT and fee-based system should be 24€/cap/year. The latter result implies that a tax-based community of 50,000 inhabitants would save about 1 million euros per year with a combination fee-based and PAYT systems. Then, the cost information and the non-zero marginal price effect on waste leads to additional cost saving as compared to situations where only one of the two systems is utilized. Driven by non-pecuniary preferences, especially intrinsic motivation, or by pecuniary preferences, households undertake costly actions to reduce their demand for MSW services, and consequently, they reduce costs for the community significantly. However, it is important to note that if the transition for communities from tax-based systems to fee and PAYT-based systems would induce cost savings for the community as a whole, the cost of MSW services could increase for some households currently benefiting from the flat-rate system.

With a focus now on the coefficients of the funding variables shown in Column (2) of Table 8, the results indicate that every PAYT schema has a cost saving effect when compared to the reference group. This ranges from 17€/cap/year for tax-based systems with pickup schemas to 27€/cap/year for fee-based systems with weight-based schemas. That is to say, households in communities with PAYT based on weight are charged 27€/cap/year less than those in tax-based communities with annexed budgets. These results are in line with the results on waste reduction described above in Tables 5 and 7: the reduction in waste collection with the PAYT schema and fee-based system is associated with cost saving for MSW services.

Combining the analysis of the coefficients of funding variables in Columns (1) and (2) of Table 8, the results firstly emphasize that the most important mechanism in the reduction of waste management costs is non-pecuniary preferences. Regardless of the supplementary reduction in the quantity of waste collected and the supplementary increase in the quantity of waste recycled due to the non-zero marginal price of waste, the marginal effect of the cost information on the waste management cost is 21€/cap/year on average. Secondly, the type of schema adopted for PAYT systems is also important for MSW reduction and cost saving. The

most efficient organization of MSW services seems to be the fee-based system with a weight-based schema. This strategy leads to a decrease in unsorted MSW collection by around 100kg/cap/year and an increase in the collection of separate MSW by around 22 kg/cap/year, which leads to a 27€/cap/year cost saving for MSW services.

5. Conclusion and policy implications

This paper contributes to the empirical literature on the effectiveness of garbage pricing (hereafter PAYT), which aims to encourage change in individual behavior by appealing to pecuniary preferences. Using original community data in France, we investigate the effects of PAYT policies both on quantities of waste collected (unsorted, separate and occasional collections) and on waste disposal fees. We consider the endogenous nature of PAYT adoption and present evidence of the preventive and substitution effects of PAYT and its cost effectiveness. Our data make it possible to distinguish the effects of the non-zero marginal price from the effects of the cost information in reference to the cost transparency of waste management. Results of the marginal effects are summarized in Table 9.

Table 9 : Synthesis of primary results

	MSW Collection (kg/cap/year)			Cost saving (€/cap/year)
	Total	Unsorted	Separate	
0. Tax system with no PAYT (Tax-system-only)	ref	ref	ref	ref
1. Tax system with PAYT (Tax-PAYT - pickup based)	ns	-56	22	-17
2. Fee system with no PAYT (Fee system only)	-23	-22	ns	-21
3. Fee system with PAYT (Fee-PAYT)	-23	-78	22	-24
PAYT schema effect				
3.1 Fee-volume-based	-19	-43	12	-24
3.2 Fee-weight-based	-84	-102	26	-27
3.3 Fee-pickup-based	-56	-70	8	-22

ns: not significant
Source: Tables 5, 7 and 8.

We confirm that the price signal is effective in changing individual behavior in regard to waste. The non-zero marginal price decreases the unsorted waste collected for disposal by 56 kg/cap/year, increases the separate waste collected for recycling by 22 kg/cap/year, and decreases the waste disposal fee by 17 €/cap/year. We found that the more refined the marginal pricing of waste is, the greater the individual response. The effectiveness of the pricing schemas in order of most to least-effective is the following: weight-based, pickup-based, and finally volume-based schema.

We have found that PAYT also appeals to non-pecuniary preferences in changing individual behavior via the cost information. Indeed, PAYT implicitly provides information on waste management costs due to the requirement of balanced budgets and individual billing. This emphasizes the importance of the cost transparency of waste management, which is itself a driving factor of waste prevention and cost saving. Allowing individuals to answer the question, "How much do MSW services cost?" increases the influence of their intrinsic motivation, including the warm-glow, the joy of giving, and altruism preferences, leading them to prevent waste production. Our findings suggest that the cost information reduces the total waste collected by 23 kg/cap/year and the waste disposal fee by 21 €/cap/year. If we apply these figures to a tax-based community of 50,000 inhabitants, the transition from tax-based system to the fee-based system without a PAYT schema would reduce MSW collection by 1,000 tons per year and save 1 million euros per year.

From a policy standpoint, our findings suggest that the non-zero marginal price and the cost information are compatible without additional effects on waste prevention and recycling for the volume-based schema. Although the implementation of PAYT policies induces an average cost of 14 €/cap/year, this does not outweigh the savings from its preventive and substitution effects (in average 38€/cap/year). However, this result should be taken with caution due to the small number of communities with a PAYT schema as of January 1, 2014 (Table 2). Furthermore, the official effective date of the PAYT programs differs among communities, and we are not able to confirm the long-term effectiveness of PAYT. Future research can address this issue with more accurate longitudinal data. In France, approximately 67% of communities fund MSW services under the tax-based system. There is certainly potential for waste prevention, recycling, and cost savings by requiring greater cost transparency in waste management and by encouraging communities to adopt a refined non-zero marginal price for MSW services based on weight or pickup schemas.

References

Abbott, A., Nandeibam, S., & O'Shea, L. (2013). Recycling: Social norms and warm-glow revisited. *Ecological Economics 90*, 10–18.

ADEME, Awiplan SARL. (2017). *Référentiel national des coûts du service public de prévention et de gestion des déchets en 2014* . Rapport - 118 p. .

Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics 95*, 1082–1095.

Allers, M. A., & Hoeben, C. (2010). Effects of Unit-Based Garbage Pricing: A Differences-in-Differences Approach. *Environ Resource Econ 45*, 405–428.

Andor, M. A., & Fels, K. M. (2018). Behavioral Economics and Energy Conservation – A Systematic Review of Non-price Interventions and Their Causal Effects. *Ecological Economics 148* , 178–210.

Angrist, J. D. (2001). Estimation of Limited Dependent Variable Models With Dummy Endogenous Regressors: Simple Strategies for Empirical Practice. *Journal of Business & Economic Statistics 19 (1)*, 2-15.

Ayres, I., Raseman, S., & Shih, A. (2013). Evidence from Two Large Field Experiments that Peer Comparison Feedback Can Reduce Residential Energy Usage. *Journal of Law, Economics & Organization 29 (5)*, 992-1022.

Bel, G., & Fageda, X. (2010). Empirical analysis of solid management waste costs: Some evidence from Galicia, Spain. *Resources, Conservation and Recycling*, 187–193.

Berglund, C. (2006). The assessment of households' recycling costs: The role of personal motives. *Ecological Economics 56 (4)*, 560–569.

Berglund, C. (2006). The assessment of households' recycling costs: The role of personal motives. *Ecological Economics 56* , 560 – 569.

Bohm, R. A., Folz, D. H., Kinnaman, T. C., & Podolsky, M. J. (2010). The costs of municipal waste and recycling programs. *Resources, Conservation and Recycling, 54*, 864–871.

Brekke, K. A., Kipperberg, G., & Nyborg, K. (2010). Social Interaction in Responsibility Ascription: The Case of Household Recycling. *Land Economics 86 (4)*, 766-784.

Bucciol, A., Montinari, N., & Piovesan, M. (2015). Do Not Trash the Incentive! Monetary Incentives and Waste Sorting. *Scand. J. of Economics 117(4)*, 1204–1229.

Carattini, S., Baranzini, A., & Lalive, R. (2018). Is Taxing Waste a Waste of Time? Evidence from a Supreme Court Decision. *Ecological Economics 148* , 131–151.

Cecere, G., Mancinelli, S., & Mazzanti, M. (2014). Waste prevention and social preferences: the role of intrinsic and extrinsic motivations. *Ecological Economics 107*, 163–176.

Choe, C., & Fraser, I. (1999). An Economic Analysis of Household Waste Management. *Journal of Environmental Economics and Management 38*, 234-246.

Costa, D. L., & Kahn, M. E. (2013). Energy Conservation "Nudges" and Environmentalist Ideology: Evidence from a Randomized Residential Electricity Field Experiment. *Journal of the European Economic Association 11 (3)*, 680–702.

Dahlén, L., & Lagerkvist, A. (2010). Pay as you throw strengths and weaknesses of weight-based billing in household waste collection systems in Sweden. *Waste Management 30* , 23–31.

Dijkgraaf, E., & Gradus, R. (2004). Cost savings in unit-based pricing of household waste: The case of The Netherlands. *Resource and Energy Economics 26*, 353–371.

Dijkgraaf, E., & Gradus, R. (2009). Environmental activism and dynamics of unit-based pricing systems. *Resource and Energy Economics 31* , 13–23.

Dijkgraaf, E., & Gradus, R. (2014). Efficiency Effects of Unit-Based Pricing Systems and Institutional Choices of Waste Collection. *Environ Resource Econ*, DOI 10.1007/s10640-014-9811-y.

Ferraro, P. J., & Price, M. K. (2013). Using Non-Pecuniary Strategies to Influence Behavior: Evidence from a Large Scale Field Experiment. *The Review of Economics s and Statistics, 95*, 64-73.

Fullerton, D., & Kinnaman, T. C. (1995). Garbage, recycling and illicit burning or dumping. *Journal of Environmental Economics and Management 29*, 78-91.

Gnonlonfin, A., & Kocoglu, Y. (2018). Tarification incitative et gestion des Déchets Ménagers : études du comportement des collectivités locales françaises.4. *FAERE Working Paper, 2018.04*.

Hage, O., & Söderholm, P. (2008). An econometric analysis of regional differences in household waste collection: the case of plastic packaging waste in Sweden. *Waste Management 28*, 1720–1731.

Hage, O., Söderholm, P., & Berglund, C. (2009). Norms and economic motivation in household recycling: Empirical evidence from Sweden. *Resources, Conservation and Recycling 53* , 155–165.

Huang, J.-C., Halstead, J. M., & Saunders, S. B. (2011). Managing Municipal Solid Waste with Unit-Based Pricing: Policy Effects and Responsiveness to Pricing. *Land Economics, 4*, 645–660.

Ino, H. (2011). Optimal environmental policy for waste disposal and recycling when firms are not compliant. *Journal of Environmenta lEconomics and Management 62*, 290–308.

Kinnaman, T. C. (2005). Why do Municipalities Recycle? *Topics in Economic Analysis & Policy 5(1)*.

Kinnaman, T. C. (2006). Policy Watch: Examining the Justification for Residential Recycling. *Journal of Economic Perspectives*, 219–232.

Kinnaman, T. C. (2010). Optimal solid waste tax policy with centralized recycling . *National Tax Journal*, 237-252.

Kinnaman, T. C., & Fullerton, D. (2000). Garbage and Recycling with Endogenous Local Policy. *Journal of Urban Economics*, 419-442.

Kirakozian, A. (2016). One Without The Other? Behavioural And Incentive Policies For Household Waste Management. *Journal of Economic Surveys 30, No. 3*, 526–551, doi: 10.1111/joes.12159.

Miliute-Plepiene, J., Hage, O., Plepys, A., & Reipas, A. (2016). What motivates households recycling behaviour in recycling schemes of different maturity? Lessons from Lithuania and Sweden. *Resources, Conservation and Recycling 113* , 40–52.

Observatoire des finances locales. (2014). *Rapport de l'Observatoire des finances locales.* Paris, ISBN: 978-2-11-138890-1.

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The Constructive, Destructive, and Reconstructive Power of Social Norms. *Association for Psychological Science 18 (5)*, 429-434.

Shinkuma, T. (2003). On the Second-Best Policy of Household's Waste Recycling. *Environmental and Resource Economics 24*, 77–95.

Sidique, S. F., Joshi, S. V., & Lupi, F. (2010). Factors influencing the rate of recycling: An analysis of Minnesota counties. *Resources, Conservation and Recycling 54*, 242–249.

Skumatz, L. A. (2008). Pay as you throw in the US: Implementation, impacts, and experience. *Waste Management 28*, 2778–2785.

Usui, T., & Takeuchi, K. (2014). Evaluating Unit-Based Pricing of Residential Solid Waste: A Panel Data Analysis. *Environ Resource Econ 58*, 245–271.

Viscusi, K., Huber, J., & Bell, a. J. (2011). Promoting Recycling: Private Values, Social Norms, and Economic Incentives. *American Economic Review 101 (3)*, 65–70.

Appendix

Table A1 : Definition of variables

Variables	Definition
Total collection	Total quantity of municipal solid waste collected, in kilograms per inhabitant.
Unsorted collection	Quantity of municipal solid waste collected through unsorted collection, in kilograms per inhabitant.
Separated collection	Quantity of municipal solid waste collected through separated collection, in kilograms per inhabitant.
Occasional collection	Quantity of municipal solid waste collected through occasional collection, in kilograms per inhabitant.
Waste disposal fee	Taxes and fees collected for waste management services, in euros per inhabitant.
Environmental activism	Proportion of regional population charged under an incentive pricing schema.
PAYT	= 1 if the community charges households under an incentive pricing schema.
After-2009	= 1 if the community implemented an incentive pricing schema after 2009.
Before-2009	= 1 if the community implemented an incentive pricing schema before 2009.
Volume-based	= 1 if the community has a volume-based schema.
Weight-based	= 1 if the community has a weight-based schema.
Pickup-based	= 1 if the community has a pickup-based schema.
Fee-based system	= 1 if the community funds the waste service under the fee-based system.
Tax-based system	= 1 if the community funds the waste service under the tax-based system.
Tax-PAYT	=1 if the community funds the waste service under the tax-based system and charges households under an incentive pricing schema.
Fee-PAYT	=1 if the community funds the waste service under the fee-based system and charges households under an incentive pricing schema
Income	Median income of household (€1000).
Urban	= 1 if the community is classified as an urban area.
Tourism	= 1 if the community is classified as touristic community.
Rural	= 1 if the community is classified as a rural area.
Private	= 1 if the community mainly uses a private firm.
Disposal-recycling subcontracting	= 1 if the population concerned by the waste collection differs from the population concerned by waste disposal or recycling.
Collection subcontracting	= 1 if the population of the community differs from the population concerned by the waste collection.
Township	=1 if the community is a town.
Syndicate	=1 if the community is a syndicate.
EPCI	=1 if the community is an "Etablissement Public de Coopération Intercommunal".
Community size	Number of town members of the inter-communal association.
Prevention programs	= 1 if the community has implemented a national waste prevention program.

Home composting	= 1 if the community has implemented a home composting program.
Separated flux	Number of waste flux at door-to-door collection.
Recycling center	Number of recycling centers.
Multi-materials schema	= 1 if the separated collection schema mixes packaging and newsprint waste (except glass).
Packaging-paper schema	= 1 if the separated collection schema involves a separated collection of packaging waste (except glass) and a separated collection of newsprint waste.
Fibrous schema	= 1 if the separated collection schema involves a separated collection of fibrous waste and a separated collection of non-fibrous waste.
Mix of schema	= 1 if the separated collection schema is a combination of the multi-materials schema, packaging-paper schema and fibrous schema.
Other schema	= 1 if other schemas for separated collection are utilized.

Figure A1: Spatial distribution of communities with a PAYT schema as of January 1st, 2014

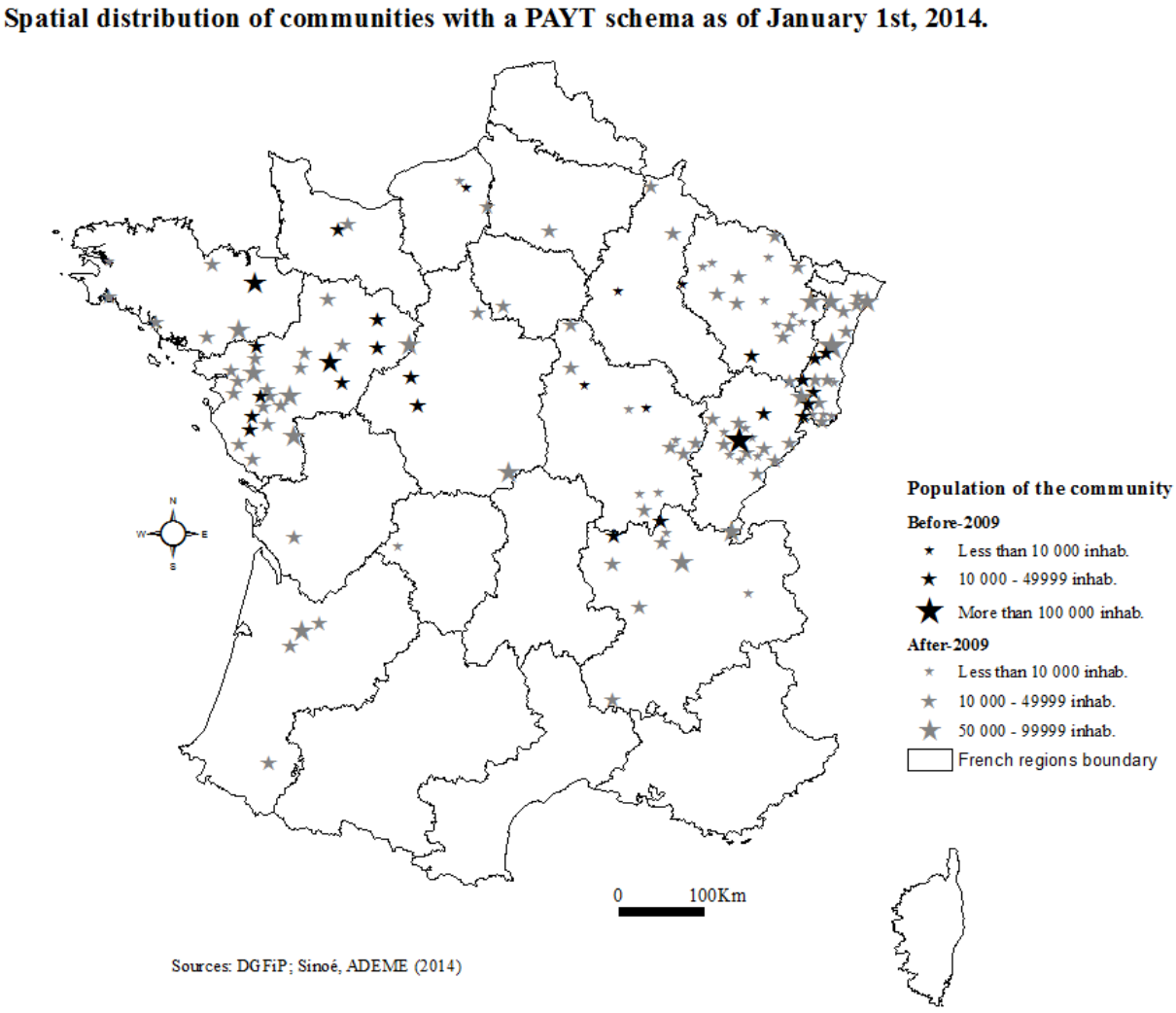


Table A2 : Stepwise results

	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
	Total collection	Total collection	Total collection	Unsorted collection	Unsorted collection	Unsorted collection	Separate collection	Separate collection	Separate collection	Occasional collection	Occasional collection	Occasional collection
Funding variables												
Fee-PAYT		-98.07***	-61.65***		-104.90***	-78.20***		12.41***	13.27***		-5.48	3.27
		(18.94)	(16.73)		(6.70)	(6.24)		(3.60)	(3.18)		(15.28)	(15.64)
Tax-PAYT		-79.93**	-45.55		-84.35***	-55.43***		14.36**	22.14***		-9.79	-12.26
		(25.23)	(28.02)		(9.68)	(11.70)		(5.74)	(6.52)		(22.94)	(26.60)
Fee-system	-39.80***	-48.71***	-22.93*	-26.45***	-30.45***	-21.85***	-4.31	-5.19*	1.97	-8.80	-12.85	-3.05
	(11.93)	(12.79)	(13.89)	(6.45)	(6.44)	(5.91)	(2.73)	(2.83)	(2.50)	(8.31)	(8.96)	(11.46)
Tax-system	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Demographic variables												
Income			0.99			-2.49**			0.89**			2.59**
			(1.51)			(0.80)			(0.29)			(1.15)
Urban			-57.08***			30.51***			-18.32***			-69.27***
			(13.26)			(5.81)			(2.43)			(10.98)
Tourism			125.43***			98.12***			10.92**			16.39
			(24.08)			(14.16)			(5.05)			(16.41)
Rural	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Control variables												
Environmental activism		-4.20	3.02		-197.33***	-105.90***		73.69***	52.49***		120.38**	56.43
		(58.32)	(48.83)		(23.54)	(17.79)		(10.58)	(9.37)		(44.48)	(45.24)
Private			-12.54			-0.34			-3.08*			-9.12
			(10.43)			(4.27)			(1.82)			(9.09)
Disposal-recycling subcontracting			-23.16**			-11.97*			-1.76			-9.43
			(11.56)			(6.24)			(1.99)			(8.36)
Collection subcontracting			-22.63			-38.67**			13.44			2.61
			(62.38)			(12.95)			(33.12)			(36.33)
Community size			-0.22			0.21*			0.18***			-0.60**
			(0.24)			(0.12)			(0.05)			(0.20)
Prevention programs			-0.62			-11.55**			4.27**			6.67
			(11.20)			(4.13)			(1.95)			(9.18)
Home composting			-17.44			-14.04**			-3.60**			0.20
			(10.60)			(4.88)			(1.76)			(8.88)
Separated flux			3.83			0.07			1.57**			2.19

			(4.09)			(2.05)			(0.72)			(3.33)
Recycling center			10.70***			-0.68			0.52			10.86***
			(2.44)			(1.13)			(0.41)			(2.05)
Waste disposal fee			1.32***			0.89***			0.13***			0.29**
			(0.22)			(0.14)			(0.04)			(0.12)
Multi-materials schema			-26.62*			-6.26			2.46			-22.83*
			(14.66)			(6.54)			(2.69)			(12.07)
Packaging-paper schema			-11.50			6.11			-6.55**			-11.06
			(16.44)			(7.00)			(2.81)			(14.46)
Fibrous schema			-14.19			-13.93			-4.21			3.95
			(18.50)			(9.22)			(3.10)			(15.10)
Mix of schema			-56.78**			-35.76**			8.51*			-29.53
			(25.46)			(11.88)			(4.65)			(20.15)
Other schema	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Constant	512.00***	521.26***	392.84***	258.62***	279.42***	235.00***	75.50***	70.10***	41.41***	177.63***	171.44***	116.43***
	(5.69)	(6.20)	(38.81)	(3.42)	(3.78)	(21.86)	(1.04)	(1.13)	(7.38)	(4.02)	(4.30)	(28.68)
N	1340.00	1340.00	1006.00	1340.00	1340.00	1006.00	1340.00	1340.00	1006.00	1340.00	1340.00	1006.00
R^2	0.01	0.03	0.37	0.01	0.14	0.58	0.00	0.07	0.25	0.00	0.01	0.13
R^2 adjusted	0.01	0.02	0.36	0.01	0.14	0.58	0.00	0.07	0.24	0.00	0.01	0.11