Policy Papers

An evaluation of French municipal solid waste pricing system

Houévoh Amandine Gnonlonfin

PP 2016-05

Suggested citation:

HA. Gnonlonfin *(2016).* An evaluation of French municipal solid waste pricing system. *FAERE Policy Paper, 2016-05.*

An evaluation of French municipal solid waste pricing system

H. Amandine Gnonlonfin

Université de Toulon, Léad (LIA-CNRS, France)

Summary

This study investigates the preventive effect and substitution effect of the Municipal Solid Waste (MSW) pricing policy in France. We examine the relationship between quantities of MSW and incentive taxes with the use of a panel of 96 French metropolitan departments between 2005 and 2011, and we use panel data and Heckman two-step estimation in order to consider sample selection. We perform the analysis for the collection of MSW and six technologies of management of the waste, namely recycling materials, composting, incineration with and without energy recovery, landfilling and dumping. We estimate the elasticity of the collection of MSW and the elasticity of these technologies in relation to three incentive taxes of the French pricing system by considering the endogeneity of municipality's decisions about both local incentive tax and technology choice. The results confirm that the French MSW pricing system has a preventive and a substitution effect and show that these effects are complementary.

Keywords: Municipal Solid Waste pricing system, User fee, Extend Producer Responsibility, tax on elimination, preventive effect, substitution effect.

JEL classification codes : H21, H23, Q53, Q56

Introduction

In the last five decades, the growth of Municipal Solid Waste (MSW) has been a growing problem in several countries. MSW management is costly and raises important environmental concerns related to the management of natural resources and pollution. To deal with these issues, some authors advocate for economic instruments because a flat fee paid by households or municipal general revenues does not depend on the quantity of waste discarded [Dubois & Eyckmans (2014), Fleckinger & Glachant (2010), Glachant (2005), Shinkuma (2003), Calcott & Walls (2000), Choe & Fraser (1999), Fullerton & Wu, 1998)].

Direct MSW pricing such as user fee, or an indirect one such as Deposit and Refund System (DRS) and Extended Producer Responsibility (EPR), can help to reduce MSW generation and improve its management. MSW pricing has two major effects: the preventive effect that provides incentive for waste reduction, and the substitution effect that provides incentive for recycling, composting and reducing elimination or disposal. In addition, these authors support that a policy, which merges direct and indirect MSW pricing instruments, is more efficient. They show that this policy allows a compromise between the incentives for illegal dumping related to the direct pricing (user fee) and the fact that indirect pricing (DRS and EPR) ignores household reduction efforts.

Therefore, in most developed countries, the regulatory framework is favorable for a combination of several incentive instruments to finance MSW management, and many empirical studies have been carried out to answer the question about the effectiveness of both preventive and substitution effects of MSW pricing. However, Kinnaman (2006) argues that most studies do not consider all incentive instruments available in the economy, and therefore the elasticity or marginal effect of the user fee is overestimated. Recent works that consider this bias and do not only evaluate the effects of user fee may be divided into household-level and community-level studies (Table 1).

Household-level studies rate the probability that some waste streams such as food waste, steel or tin cans, newsprint, glass, cardboard and paper, and toxic chemicals, will be recycled when municipalities implement a user fee and curbside recycling programs. Community-level studies estimate elasticity and marginal effect under the same conditions. This literature shows that user fee and curbside recycling programs are empirically complementary. The preventive and substitution effects are jointly significant in all studies in Table 1. However, there is no consensus on the question about the superiority of the user fee on curbside recycling programs, and vice versa. Furthermore, we note that there is no work on French MSW pricing system. Consequently, there is more be known about the effectiveness of this system at reducing waste and increasing recycling.

Table 1: MSW pricing system effectiveness

References	Field and year of study	Econometric model	Dependent variable	User fee effect	Curbside recycling program	
					Incentive financing [a]	Other financing [b]
Household-level studies						
Saphores & Nixon (2014)	Surveys in USA (2006)	Ordered Logit	Materials recycling rate[+]	1.65	1.28-3.07	1.38-19.39
Kipperberg (2007)	Surveys in Norway (1999)	Ordered Probit	Materials recycling rate[+]	0.25-0.64	0.26-1.50	n.s.
Ferrara & Missios (2005)	Surveys in Ontario province (2002)	Ordered Probit	Materials recycling rate[+]	0.18 - 0.32	0.25 - 0.40	-
Community-level studies						
Usui & Takeuchi (2014)	665 Japanese cities (1996-2002)	Panel	Quantity collected [+++]	(0.038)	(0.012)	n.s.
			Quantity eliminated[+++]	(0.058)	(0.014-0.32)	n.s.
			Quantity recycled[+++]	0.119	0.045-0.252	0.144
Allers & Hoeben (2010)	458 municipalities in Netherlands (1998-2006)	Panel	Quantity collected [+++]	(0.32-0.87)	n.a.	-
			Quantity recycled[+++]	0.04	n.a.	-
Lakhan (2015)	223 municipalities in Ontario province (2003-2012)	Panel	Materials recycling rate [++]	1.95 - 3.01	4.4-6.6	-
Sidique et al. (2010)	86 Counties in Minnesota province (1996-2004)	Panel	Materials recycling rate[++]	1.62 - 4.19	0.010-0.015	2.10-2.96
Kuo & Perrings (2010)	12 Japanese cities and 6 cities in Taiwan (1998-2003)	Panel	Quantity collected[++]	(1980)	-	(223)
			Quantity eliminated[++]	(2424)	-	(82-264)
			Quantity recycled[++]	40-171	-	3-62

Suwa & Usui (2007)	Japanese Municipalities (1997-1998)	Heckman 2step	Quantity collected++	(28.04)	(34.98)	-
			Quantity recycled++	5.37	34.98	-
Yang & Innes (2007)	7 cities in Taiwan (1997-2004)	OLS	Quantity collected++	(8.65)	-	(19.88)
			Quantity recycled++	ns	-	ns
Callan & Thomas (2006)	351 cities in Massachusetts	3SLS	Quantity eliminated++	ns	-	(1.91)
			Quantity recycled++	0.007	-	8.121^{E-6}

+: probabilities ; ++ : marginal effect ; +++ : elasticities ; (.) : negative value, n.a. : significant but not available; n.s. : not significant, a : EPR or DRS financing; b : general revenues and other financing.

The design of the French MSW pricing system began in the 1970s with the REOM[1] tax, which allows municipalities to charge MSW management services proportionally to the weight or volume they collect. The REOM is a local tax and has the features of user fee. Each municipality can finance MSW management cost with this tax or with the flat fee or the general revenues.[2] In 1990 and 2000, two national taxes, the Extended Producer Responsibility (EPR) and the tax on polluting MSW management technologies (TGAP[3]), complemented the French MSW pricing system. The EPR finances the curbside recycling programs for glass, packaging materials, paper and newsprint, food waste, hazardous waste and bulky waste. The TGAP is a disposal tax paid by municipalities according to the weight of MSW they landfill, incinerate or dump. Both local tax (REOM) and national taxes (EPR and TGAP) are designed to encourage households to prevent waste production and to recycle, and they help to finance about 45% MSW management cost in 2011 (ADEME, 2014-a). Because all three taxes have the same objective, do they jointly have preventive and substitution effects, and if so, by how much?

This paper aims to examine the effects of the French MSW pricing system on MSW collection (at door and at curbside), recycling and elimination. We use aggregated data at the departmental[4] level from 2005 to 2011, to rate the household demand elasticity for MSW collection and for the six MSW management technologies available in France. These are recycling materials, recycling organic waste (composting), incineration with energy recovery, incineration without energy recovery, landfilling and legal dumping.

Our paper makes three main contributions to the community-level studies. First, and perhaps the most important, we consider the behavior of a municipality in the choice of the available MSW management technologies. Only Suwa and Usui (2007) address this problem, which can introduce selection bias in the estimations. Because each municipality has three recycling technologies (recycling materials, recycling organic waste and incineration with energy recovery) and three elimination technologies (incineration without energy recovery, landfilling and dumping), estimating household demand using data that include some departments that do not offer a kind of MSW management technology, will cause a bias in coefficients. The household demand depends on the availability, or not, of a technology in

[1] Redevance d'Enlèvement des Ordures Ménagères.
[2] Flat fee or general revenues are independent of the amount of waste households discard.
[3] Taxe Générale sur les Activités Polluantes-Déchets Ménagers et Assimilés.
[4] "Department" is one of the three main administrative divisions in France. There are, overall, 100 administrative departments, four of which are overseas.

its municipality. This demand is equal to zero if the technology is not available. First, a municipality makes its technology choice based on national incentives taxes and household characteristics. Second, households express their demand. Deleting zero values in order to keep only the positive observations may generate a selection bias due to the non-exogeneity of a municipality's choice.

Second, studies cited in Table 1 estimate the aggregate demand for recycling and elimination technologies. We simultaneously estimate the demand for the six available technologies as a function of incentive taxes, household characteristics and other relevant variables. Furthermore, earlier studies combine continuous and dummy variables to measure incentive taxes. Here, we use only continuous variables. This allows us to test the hypothesis of the marginal decreasing effect of incentive taxes. Third, we do not only control for REOM tax endogeneity; we also inspect whether or not spatial correlation of this tax biases estimations.

The rest of this paper is organized as follows. The next section presents the model of household's demand for MSW collection, recycling and disposal. Sections 2 and 3 describe the data and the empirical strategy used in this study. Section 4 presents estimation results, and Section 5 contains the concluding remarks and policy implications.

1. French Household demand for MSW collection, recycling and disposal

This section describes the econometric models used to investigate the household demand for Municipal Solid Waste (MSW) collection and management. We focus on the effects of the French MSW pricing system, which encompasses local and national incentive taxes on the quantity of MSW collected, recycled and disposed of. Thus, the aim of this study is to evaluate preventive and substitution effects of incentive taxes as predicted in the theoretical literature [Kinnaman (2010), Glachant (2005), Calcott & Walls (2000), Choe & Fraser (1999), Fullerton & Kinnaman (1995)].

As in most countries around the world, French municipalities are responsible for collection and management of household solid waste. However, they can ensure this responsibility in inter-communal associations or structures called "Établissement Public de Coopération Intercommunale (EPCI), and are free to choose between local incentive tax (REOM), flat fee or general revenues to finance management cost. They are not legally required to offer curbsides collection of recyclable materials, but they are supported by both national incentive taxes, namely Extended Producer Responsibility programs (EPR) and the national fee on polluting MSW management technologies (TGAP). Since 1990, several MSW flows have been concerned by French policy, which is based on the principle of EPR (ADEME, 2014). Therefore, municipalities or inter-communal structures (hereafter called local government) have been implementing curbside recycling programs for glass, packaging materials, paper and newsprint, food waste, hazardous waste and bulky waste. The local government pays for TGAP tax, based on the quantity of MSW for incineration, landfilling and dumping. By contrast, the REOM tax is the French user fee. It allows local government to bill households according to the weight or volume of MSW they dispose of.

Our theoretical framework follows Kinnaman and Fullerton (2000)'s model to rate REOM, EPR and TGAP effects on household's MSW demand. Total MSW collected by local government (unsorted and separate ones) are recycled or disposed of. Recycling involves materials[5] recycling, composting and energy recovery, and disposal involves incineration, landfilling, legal dumping and illegal dumping.

$RMat$, $RComp$, $REnerg$, $DInci$, $DLand$, $DLDump$ and $DIDump$ are the household demand for the respective recycling materials, composting, energy recovery, and disposal, which involves incineration, landfilling, legal dumping and illegal dumping. These demands[6] depend on recycling price (P_r), disposal price (P_d), illegal dumping price (P_{id}) and household's characteristics (α).

$$\boldsymbol{RMat = RMat(P_r, P_d, P_{id}, \alpha)} \quad 1$$

$$\boldsymbol{RComp = MComp\ (P_r, P_d, P_{id}, \alpha)} \quad 2$$

$$\boldsymbol{REnerg = MEnerg(P_r, P_d, P_{id}, \alpha)} \quad 3$$

$$\boldsymbol{DInci = DInci(P_r, P_d, P_{id}, \alpha)} \quad 4$$

$$\boldsymbol{DLand = DLand(P_r, P_d, P_{id}, \alpha)} \quad 5$$

$$\boldsymbol{DLDump = DLDump(P_r, P_d, P_{id}, \alpha)} \quad 6$$

$$\boldsymbol{DIDump = DIDump(P_r, P_d, P_{id}, \alpha)} \quad 7$$

For a given quantity of MSW that can be recycled or disposed of, a household arbitrates between two prices (P_r and P_d) according to its characteristics (income, age, population

[5] Glass, paper, newsprint, plastic, steel can, etc.
[6] For details, see Kinnaman and Fullerton (2000).

density, etc.). The disposal price (P_d) includes the local incentive tax (REOM) and the household's time for sorting the waste,[7] which is a function of its characteristics (α) and supports received by its local government to implement curbside programs. In turn, these supports depend on national incentive taxes (EPR and TGAP) and the decrease in households sorting efforts and then, household disposal price P_d. Other variables that relate to the way the MSW management is organized in the municipality (O), might also affect P_d. For example, clustering in inter-communal structures or contracting private firms can allow economies of scale in the costs of MSW and reduce P_d by minimizing the REOM tax. The recycling price (P_r) is the households' opportunity cost, which includes the efforts needed to separate different types of waste and to drop them at the appropriate curbside. Likewise, P_r depends on household characteristics (α), MSW management organization in the local government and national incentive taxes. Finally, illegal disposal (P_{id}) includes the time needed to transport, find a suitable dumping place and the fine of illegal dumping. Once again, this price is based on household characteristics (α) and the MSW management organization in the local government (O). For example, it will be easier to find an illegal dumping place in low density areas, and more difficult if the local government sets up an effective monitoring illegal dumping system. By assumption, the REOM tax is equal to zero if the local government does not have effective monitoring system:

$$RMat = RMat(REOM, TGAP, REPs, O, \alpha) \qquad 8$$

$$RComp = RComp(REOM, TGAP, REPs, O, \alpha) \qquad 9$$

$$REnerg = REnerg(REOM, TGAP, REPs, O, \alpha) \qquad 10$$

$$DInci = EI(REOM, TGAP, REPs, O, \alpha) \qquad 11$$

$$DLand = DLand(REOM, TGAP, REPs, O, \alpha) \qquad 12$$

$$DLDump = EMD(REOM, TGAP, REPs, O, \alpha) \qquad 13$$

$$DIDump = DIDump(REOM, TGAP, REPs, O, \alpha) \qquad 14$$

Because the total of MSW collected (W) is equal to the sum of recycled and disposal MSW, we can write it as function of the incentive taxes, the household characteristics and the MSW

[7] Especially time effort to separate, to store and put materials in curbsides.

management organization in the local government. In the same way, aggregated MSW recycled and disposed of waste can be written as follows:

$$W = W(REOM, TGAP, REPs, O, \alpha) \quad 15$$

$$R = R(REOM, TGAP, REPs, O, \alpha) \quad 16$$

$$D = D(REOM, TGAP, REPs, O, \alpha) \quad 17$$

Equations (8-17) are simultaneously determined, but as the exogenous variables that they include are identical, they may be estimated separately without introducing a bias. Because MSW illegally dumped ($DIDump$) is not observed, we cannot estimate equation (14) and based on (8-13 & 15-17), we estimate household MSW demand of the following specification:

$$Q_{it} = \beta_0 + \beta_1(REOM_{it}) + \beta_2(TGAP_t) + \beta_3(EPR_t) + \beta_4 X_{2_{it}} + \beta_5 X_{3_{it}} + u_{it}, \quad 18$$

where Q_{it} denotes either the per capita MSW collected (W), MSW recyced ($RMat$, $MComp$, $MEnerg$) or MSW disposed of ($DInci$, $DLand$, $DLDum$p) for local government i in year t; $ROEM_{it}$ denotes the marginal local tax in local government i and in year t; EPR_t and $TGAP_t$ are indicator variables for national incentive taxes ; $X_{2_{it}}$ and $X_{3_{it}}$ are vectors of time-varying household's and local government's characteristics; and u_{it} is an error term.

However, equation (18) is especially valid for the estimation of household MSW demand on aggregated quantities, for example total MSW collected (W), total MSW recycled (R) or total MSW disposed of (D). As discussed above, local governments are not legally required to offer all MSW management technologies in their jurisdiction. Therefore, the observed household demand for some technologies is equal to zero, because they are not available. In this case, when a panel-data estimation method is applied, a serious selection bias will arise. The estimator's consistency will be affected, because samples are censored as a result of a specific local government's decision. We consider that this decision is endogenous because each local government compares costs and benefits of implementing a given MSW management technology. Costs include capital investment, ordinary spending and national incentive tax on disposal (TGAP), while benefits include income from the sale of recycled waste (materials, energy, and compost), subsidies from EPR policy and other avoided social costs. Both costs and benefits are not observed directly, but we define the difference between benefits and costs as a latent variable (BC) that can be either negative or positive. This difference is a function of household characteristics, national incentive taxes and the type of management of MSW in the local government. For example, the decision to manage MSW in inter-communal structures or population density can allow economies of scale in costs. We suppose that there is a decision threshold BC_j^* and when BC_j becomes greater than this threshold, a local government i decides to offer the technology j in its jurisdiction. We have:

$$\begin{cases} O_i = 1 \; if \; BC_j > BC_j^* \\ O_i = 0 \quad otherwise \end{cases} \qquad 19$$

Eventually, the exogenous variables in equation (18), except for the local incentive tax, determine first the local government's decision about the choice of MSW management technology, and second, determine the household demand. Furthermore, we suppose that households do not have information on the type of management of MSW management in their local government, or at least they do not take this information into account. To consider a sequence of decisions by local governments and households, we employ Heckman's two-step estimation method (Heckman 1979).

$$Q_i = \gamma_0 + \gamma_1(REOM) + \gamma_2(EPR) + \gamma_3(TGAP) + \gamma_4 X_2 + \theta \qquad 20$$

knowing

$$O_i = \alpha_0 + \alpha_1(TGAP) + \alpha_2(EPR) + \alpha_3 X_2 + \alpha_4 X_3 + \varepsilon > 0, \qquad 21$$

where X_2 and X_3 are vectors of household and local government variables, respectively; error terms θ and ε are supposed normal and correlated: $\varepsilon \sim N(0,1)$ $\theta \sim N(0,\sigma)$ and $\rho(\theta,\varepsilon) \neq 0$. In the first step, we employ a Probit estimation to identify the factors that affect the local government's decision concerning the choice of technology. In the second step, we add an inverse Mill's ratio, derived from the Probit estimation, to the explanatory variables to obtain a consistent estimator in the second regression equation.

2. Data

For the purposes of this study, we gather departmental-level data from "Eider" and Sinoe" databases provided by ADEME[8] and the French Ministry of Ecology, Sustainable Development and Energy. These data are assembled through a biennial survey sent to independent municipalities or inter-communal structures by ADEME since 2005. Data on incineration plants are provided by the national center for independent information on waste[9]

[8] ADEME is the French national agency responsible for environmental issues.
[9] Centre national d'information indépendante sur les déchets (Cniid).

(CNIID) and the national union of urban and similar waste treatment.[10] This section provides a description of MSW collection and management in France over the period 2005-2011.

Summary statistics for 384 observations (96 French metropolitan departments for 4 years) appear in Table 2 and Table 3. Table 2 shows means and standard deviation of dependent variables used in the estimations. During the period 2005-2011, each department collected at door and at curbsides, 400 kg of MSW per inhabitant and per year. MSW collected was managed through six technologies. Landfilling, the first technology used in France over this period, comprises 37% of MSW collected. . This is followed by waste incineration with energy recovery (32%), recycling materials (20%), recycling organic waste (6%), dumping (3.5%) and incineration without energy recovery (1.5%).

Table 2: Definition of dependent variables and summary statistics

Definition (Kg/cap./year)	Mean.	S.D.	Min	Max
MSW collected « *W* »	399.52	63.30	274.88	894.40
Recycled materials « *RMat*»	79.58	22.97	6.60	238.12
Recycled organic waste « *RComp* »	23.91	31.27	0	163.76
Incinerated waste with energy recovery « *REnerg*»	127.53	111.12	0	406.24
Landfilled waste « *DLand* »	147.74	125.94	0	824.92
Incinerated waste (without energy recovery) « *DInci* »	6.73	23.44	0	185.85
Dumped waste « *DLDump*»	14.04	39.71	0	390.34

Table 3 summarizes independent variables. The REOM tax is very flexible and has been implemented by local government in many forms. The four common forms of the REOM are frequency-based system, weight-based system, bag program and tag or sticker programs. In order to achieve a comparable price, we simply ignore differences in programs and calculate the marginal REOM by dividing the total of REOM revenues by the amount of MSW disposed of.[11] The variation in this tax is significant, with a range from 0€/tonne to 374€/tonne. Figure 1 and Figure 2 show departments in which the average REOM is lower and greater than the median[12] over 2005-2011, respectively. The national tax on polluting MSW management technologies (TGAP) is an average effective rate set by finance law in 1999 and 2009. Eventually, EPR programs are measured by percentages of population with access to different selective collections. Selective collections are mainly financed by producer-responsible organizations, which collect eco-participations per weight and type of

[10] Syndicat national du traitement et de la Valorisation des Déchets Urbains et assimilés.
[11] Sum of MSW go for landfilling, dumping and incineration (with and without energy recovery).
[12] This ranged from 23€/tonne to 35€/tonne over 2005-2011.

packaging materials or per unit of product that each producer puts on the market. We then consider that a higher percentage of the population has access to selective collections, the more efficient the EPR programs are. Further, we note that over 80% of selective collections go for recycling.

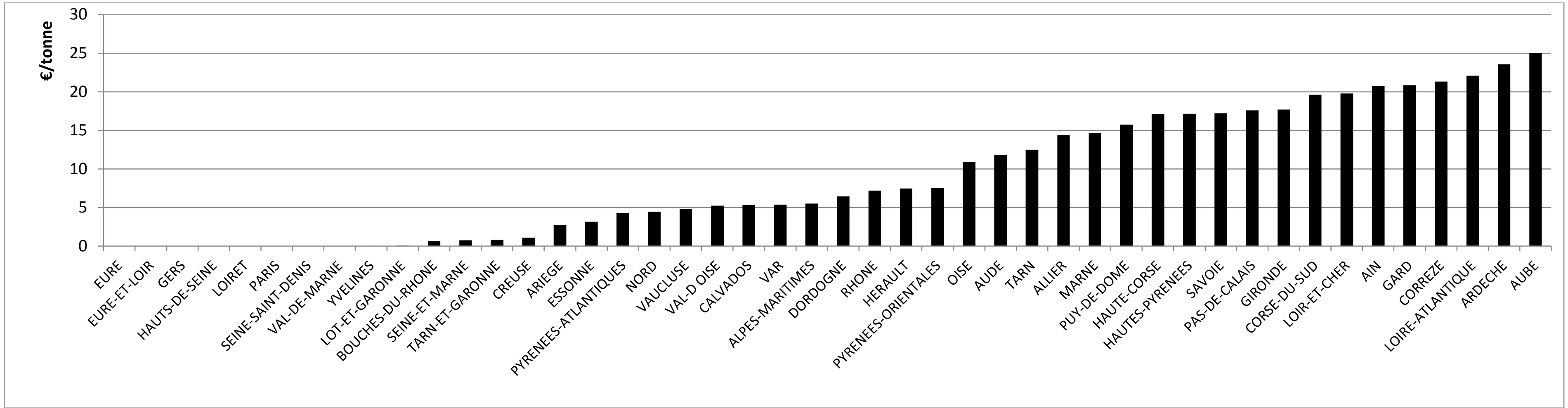
Table 3: Definition of independent variables and summary statistics

Definition	Mean.	S.D	Min	Max
Local and national incencitive taxes				
Local incentive tax (€/tonne) « *REOM* »	46.1	57.6	0	373.8
National fee on polluting MSW management technologies (€/tonne) « *TGAP* »	13.3	3.4	8.5	174
% of population with access to glass selective collection « *tcs_glass* »	96.21	11.66	3.5	100
% of population with access to packaging, newspapers and magazines selective collection « *tcs _EJM* »	97.70	6.75	41.66	100
% of population with access to bulky selective collection « *tcs _bulky* »	39.97	32.97	0	100
% of population with access to organic waste selective collection « *tcs _BDDV* »	27.37	25.27	0	98.60
% of population with access to hazardous waste selective collection « *tcs_DD* »	12.09	20.90	0	100
Household's variables (X_2) in equations				
Mean income (euro/cap.) « *Rev* »	21,160	2,492	17,737	36,875
Hotels rooms (number/1000 hab.) « *Rooms* »	10	10	30	80
% of population that are 60 years and older « *Pop_60+* »	24.04	4.14	14.18	34.54
Density (hab./km^2) « Dens »	550	2423	15	21,304
Sum of annual hours of sunshine de nombre (hour/year) « *sunshine* »	2,041	362	940	3,058
Department's variables (X_3) in equations				
Number of inter-communal structures « *Numb_IS* »	27	12	1	65
% of population that belong to a inter-communal structure « *Inter-communal_Rate* »	96.8	5.1	64	100
Number of inter-communal structures that delagate mix MSW collection « *del_mix_collection*»	3.27	5.13	0	25
Number of inter-communal structures that delagate selective MSW collection « *del_select_collection* »	8.64	11.62	0	66
Number of inter-communal structures that delagate MSW management « *del_management* »	12.72	10.50	0	44
Legal capacity of incineration plants (kg/cap./year) « *incineration_capacity* »	193	182	0	851
Average age of incineration plants « *inc_plants_age* »	12	11	0	38

Table 3 also shows that households and departments display considerable variations in economic, demographic and MSW management characteristics. For example, the number of rooms in hotels varies from 30 per thousand individuals to 80 per thousand individuals, density population varies from 15 per square mile to 21,304 per square mile and the sum of annual sunshine varies from 940 hours to 3,058 hours. With regard to MSW management, at least 60% of the population belongs to inter-communal structures and they are, on average, 27 per department. However, the number of these structures that delegate mixed collection, selective collection or MSW management, varies widely across departments, as and also varies by the capacity and age of incineration plants.

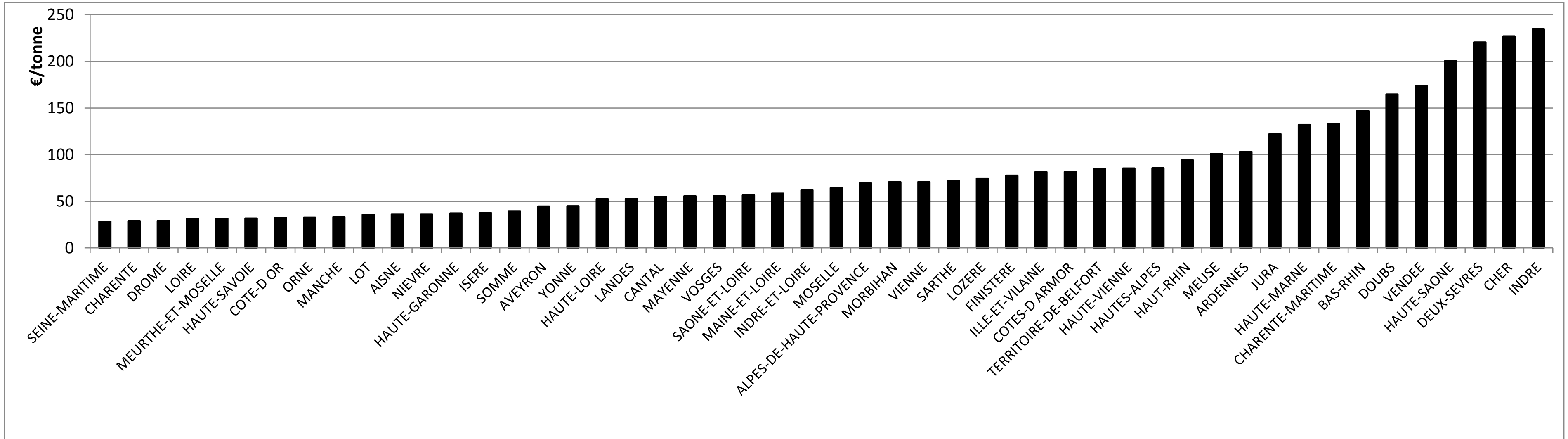
Previous studies (Table 1) have directly estimated the effects of incentive taxes on total MSW collected, recycled and eliminated. Here, in addition to estimating their preventive effect on total MSW collected, we are able to estimate the substitution effect on six recycling and elimination technologies used in MSW management.

Figure 1: Departments in which the average REOM is lower than the median (over 2005-2011)



Source: Ministry of Ecology, Sustainable Development and Energy

Figure 2: Departments in which the average REOM is lower than the median (over 2005-2011)



Source: Ministry of Ecology, Sustainable Development and Energy

3. Estimation strategy

As shown in Table 2 that presents the summary statistics of dependent variables, some of variables have "zero" for minimum value. This may generate a selection bias that is common for truncated samples. We assume that the selection bias is significant when the percentage of the dependent variable that takes the value "zero" is greater than 15%. That is the case for the composted-organic-waste model (16%), incinerated-waste models [with energy recovery (19%) and without energy recovery (87%)] and the dumped-waste model (30%). Therefore, we use the Heckman two-step estimator (equations 20 & 21) to control for local government decision on household demands. The level of significance of inverse Mill's ratio confirms the selection bias assumption. In the other case, we directly estimate the household demand with equation (18) by appliying a panel estimator.[13] The estimations' standard errors are robust to heteroskedasticity.[14] All models are estimated in double natural log in order to evaluate the elasticities of household demands in relation to incentive taxes. In addition to the independent variables described in Table 3, we include in the models, two interaction variables between local and national incentive taxes in order to capture other complementary effects between taxes (REOM_EPR on the one hand, and ROEM_TGAP on the other hand). We perform three main tests that lead to the identification of optimal models.

The first is the multicollinearity test. There is a possibility that the estimations suffer from multicollinearity, because the proxy of EPR programs (Tcs_ variables) and department's variables may be highly correlated. The calculation of VIF statistics and correlation between these variables allows us to select relevant ones.

The second test aims to control incentive taxes endogeneity. Several studies show that incentive instruments to control MSW demands are well endogenous [Usui & Takeuchi (2014), Sidique et al. (2010), Allers & Hoeben (2010), Dijkgraaf & Gradus (2009), Callan & Thomas (2006), Kinnaman & Fullerton (2000)]. A local government's decision about incentive taxes may be endogenous for different reasons. For example, some of them may be likely to apply incentive taxes because the potential benefits of waste reductions are larger. In the French case, the fact that the local government makes the decision whether or not to apply the REOM tax, can lead the variable to be endogenous. Hausman and

[13] We carefully choose our panel model among fixed-effect and random effects after the Hausman test. In the end we select the fixed-effect model.
[14] We also use the Breusch-Pagan LM test for heteroscedasticity and do a sensibility test for Heckman two-step models.

Wooldridge (2006)'s endogeneity tests confirm this intuition. We try several variables as candidates for instrument including total waste collected, recycled and disposed of, incineration plants' capacity and selective collection rate. We retain the variable REOM delayed- order 2 as a valid instrument. We confirm this choice by the Stock and Yogo (2005) test (Table 5). Also, the endogeneity bias may be caused by the omission of the threshold effect of incentive taxes. We therefore check for the presence of any nonlinearity effects of incentive taxes by including in the estimations the square of both REOM tax, TGAP tax and proxy of EPR programs.[15]

The third test aims to control spatial autocorrelation for REOM tax. As pointed out by many studies in France, competition between local governments leads to a spatial clustering of local governments with similar tax rates [Leprince et al. (2005, 2007), Madiès et al. (2005), Cassette & Paty (2006), Jayet et al. (2002), Feld et al. (2002)]. This suggests that the tax rate in one local government depends on the tax rate in nearby jurisdictions. The REOM tax may be applied in a given local government if neighboring jurisdictions have already introduced such a tax. Local governments may be reluctant to adopt the REOM because they fear problems such as illegal dumping and waste tourism. Households can illegally dump their waste to avoid the REOM, and the high level of the REOM in neighboring jurisdictions may cause an influx of waste. If neighboring jurisdictions have introduced the REOM without encountering such problems, the likelihood that a given local government applies the REOM in its jurisdiction may be higher. For the same reasons, the REOM rate in a specific jurisdiction may depend on the REOM rates in neighboring jurisdictions. If this intuition is true, errors in our models will be spatially correlated. Spatial autocorrelation tests reject this hypothesis (Table 5).

In summary, the optimal estimations presented in the next session are: panel-IV fixed effects for the MSW collection model, panel fixed effects with incentive taxes at square for the recycling materials model and landfilling model, Heckman two-step for the recycling organic waste model, incineration with and without energy recovery models and the dumping model.

[15] Our test strategies are: (1) we apply the Hausman test for endogeneity to choose between the panel models and panel-IV models and (2) we apply the Hausman test to choose between the panel-IV models and models with square variables.

4. Results

4.1. Estimation of local government decision

At first glance,

Table **4** presents the results of the Probit estimation from the first step of the Heckman model defined in equation (21). The results show the factors that affect a local government's decision about MSW management technology choice. First, the results indicate that the correlation (rho) between errors of equations (20) and (21) is different from zero. Consequently, applying panel models to estimate household's demands will yield biased results. The Heckman estimator is consistent for technologies of recycling organic waste, incineration (with and without energy recovery) and dumping. However, the inverse Mill's ratio (lambda), which measures the selectivity or non-selection hazard, is significant for technologies of incineration and dumping. This confirms the significance of the selection bias and indicates that there is an underlying relationship between local government's decision about these technology choices and household demand. This relationship is negative (sign of lambda) for incineration technologies, and means that local government decision is out of step with the household demand. Unlike dumping, current characteristics of households do not justify the choice of these technologies.

Second, the incentive taxes, the characteristics of households and the characteristics of MSW management in the department, are determinants for technology choice. National incentive taxes directly impact local government decisions. While the TGAP increases the probability that each local government will choose incineration without energy recovery and this decreases the probability of the choice of dumping, EPR programs foster the choice of recycling organic waste and incineration with energy recovery. The interaction between the local incentive tax, REOM, and EPR programs leads local governments to choose the dumping. Among household characteristics, income, population aged 60 years and over and population density are significant. For example, income and population aged 60 years and over have a positive effect on the selection of the incineration with energy recovery. This suggests that a local government with high-income and a high percentage of older population is inclined toward the incineration with energy recovery. The coefficient of population density is estimated positively on the recycling organic waste and the dumping; this means that these technologies tend to be implemented in urban areas.

Table 4: Estimation results for local government's decision

Variables[16]	MSW management technologies			
	Recycling organic waste	Incineration with energy recovery	Incineration without energy recovery	Dumping
REOM_EPR	-	-	-	0.4008**
TGAP	-	-	44.5363**	-1.4928***
$(TGAP)^2$	-	-	4.9595**	-
Tcs_BDDV/ Tcs_bulky	26.7594***	4.4320**	-	-
$(Tcs\_BDDV/ Tcs\_bulky)^2$	-33.7875**	-8.9450**	-	-
Tcs_DD	-	8.3882*	-	-
Income	-	3.8480**	-3.5219**	-
Pop_60+	-	2.1259*	-	-
Density	0.3512**	-	-	0.4936***
Inter-communal_Rate	-	-	-3.6204*	-
Numb_IS	1.1414***	-	0.5774**	0.4631**
Incineration_capacity	-	0.4118**	0.3345**	-0.0608*
Constant	-4.6473***	-37.4447**	148.3286**	-9.5576***
lambda	0.1754	-2.6051***	-1.1565**	0.9520*
N	384	384	384	384
N_cens	62	74	334	115
P (chi2)	0.0000	0.0000	0.0000	0.0000
sigma	1.0433	2.6114	1.1478	1.3638
rho	0.1681	-1.0000	-1.0000	-0.3878

- : not significant, * $p < 0.10$, ** $p < 0.05$, *** $p < .001$

Regarding characteristics of MSW management in the department, the coefficient for the percentage of population that belongs to an inter-communal structure is estimated negatively, implying that clustering of municipalities in inter-communal structures eases the abandonment of the incineration without energy recovery. By contrast, the higher is the number of inter-communal structures, the greater is the probability of selecting recycling organic waste, incineration without energy recovery and dumping. Our data supports this hypothesis that the concurrence between inter-communal structures decreases the costs of these technologies and allows local governments to choose them. The estimations also suggest that the probability of selecting the incineration with and without energy recovery

[16] Variables in natural log. Insignificant variables are deleted to save space.

increases with the incineration capacity of the department. This probability decreases for the dumping. Local governments invest in incineration plants in order to abandon the dumping. Although results for local government's decision presented in Table 4 are useful and interesting in their own right, results for household's demand shed more light on the issue.

4.2. Estimation of household's MSW demand

At the last stage of our study, we use equations (18) and (20) to estimate the household demands for MSW collection and management technologies in order to reach our ultimate goal to test the preventive and substitution effects of incentive taxes. Table 5 presents the elasticity of dependent variables related to independent ones, and results confirm the preventive effect of the three incentive taxes. All three incentive taxes conjointly have a negative elasticity. A 1% change in the REOM and the TGAP decreases the amount of waste collected per capita by 0.68% and 0.08%, respectively. When the percentage of population with access to packaging-newspapers-magazines and hazardous waste selective collection increases by 1%, the amount of waste collected per capita decreases by 0.08% and 0.17%, respectively. The preventive effect of local tax, REOM, is three times greater than the effect of EPR programs and seven times greater than the effect of TGAP. This confirms the joint significance of incentive taxes on MSW collection identified in previous empirical studies (Table 1). Specifically, our results are comparable to those of Usui and Takeuchi (2014), Allers and Hoeben (2010) and Kuo and Perrings (2010), which show the superiority of the preventive effect of user fee on the curbside recycling program. The weakness of the elasticity of the TGAP tax can be explained by the fact that it is paid by local governments, and therefore does not directly affect household collection demand.

Results also confirm the substitution effect between MSW management technologies in France. Household demand is very sensitive to the REOM tax. A 1% increase in the REOM tax increases the demand of recycling organic waste by 8.70% and decreases the demand of landfilling, incineration with and without energy recovery by 5.48%, 3.57% and 21.49%, respectively. However, we detect a decreasing marginal effect of REOM on the demand for incineration without energy recovery with a threshold at 1.07 euro/kg of waste disposed of.[17] The substitution effect of TGAP tax occurs between the demand of recycling materials and dumping. When the TGAP tax increases by 1%, the demand for recycling materials increases by 14.38%, and the demand for dumping decreases by 1.99%. The period of our study can

[17] $TP = e^{\frac{21,48}{2*168,62}}$

explain the high value of these elasticities. Indeed, this period (2005-2011) matches up with the beginning of the implementation TGAP tax (2000). We believe that local government and households had about five years of an adjustment period before changing their behavior.

Regarding the EPR programs, selective collections led to the substitution of demand of incineration without energy recovery and dumping to demand of recycling materials, recycling organic waste and incineration with energy recovery. For example, the elasticity of the recycling materials and organic waste in response to selective collection of packaging-newspapers-magazines collection is positive (1.63; 9.99) with increasing marginal effect, while elasticity of the dumping is negative (-3.60).

Further, we note that many control variables are significant and have the expected signs. Income, rooms in hotels, sunshine, population age and density are determinants in a household's decision. Income variable has a negative effect on the demand of incineration without energy recovery and dumping, but a positive effect on the demand for landfilling. This suggests that in departments with households that have a high level of income, less quantities of MSW go for incineration and dumping. The number of rooms in hotels, which indicates the tourism activity in the department, has a positive effect on MSW collection and quantities for energy recovery technology. Tourism activities increase the local consumption and therefore the quantity of MSW collected. The percentage of the older population is significantly negative on both recycling and elimination technologies, namely recycling materials, energy recovery and dumping. Most previous studies have found that the older populations have a low opportunity cost for recycling. They have more free time and consumption preferences that allow them to separate out recyclable waste. Our estimations do not support this result. Perhaps the French curbside collection system is not suited to the lifestyle of elderly people, as it may be difficult for them to access it. Population density is found to have a negative effect on incineration without energy recovery. In other words, urban areas send less MSW to incineration. We also estimate that the variable of sunshine negatively impacts the demand of recycling organic waste and energy recovery technologies. This result supports the hypothesis that the number of sunshine hours is a determinant in household recycling opportunity cost.

Table 5: Estimation results for household's demand

Variables[18]	MSW collection	MSW management technologies					
		Recycling materials	Recycling organic waste	Incineration with energy recovery	Incineration without energy recovery	Landfilling	Dumping
REOM_TGAP	-	0.1723**	-	-	-	-	-
REOM_EPR	0.0699***	0.3337***	-	-0.4106**	0.8914**	-	-
ROEM	-0.6821**	-	8.7063***	-3.5690**	-21.4875*	-5.4771***	-
$(ROEM)^2$	-	-	-	-	168.6277*	-	-
TGAP	-0.0761**	14.3797**	-	-	-	-	-1.9862***
$(TGAP)^2$	-	1.6077**	-	-	-	-	-
Tcs_EJM	-0.1739**	1.6248*	9.9853***	3.4683**	-	-	-3.6037**
$(Tcs\_EJM)^2$	-	2.8200**	20.3294***	-	-	-	-
Tcs_encombrant/ Tcs_BDDV	-	-	3.9147***	-	-1.8673*	-	-
Tcs_DD	-0.0827**	-0.6946**	-	-2.0481***	-	-	-4.7234**
$(Tcs\_DD)^2$	-	1.0432*	-	-	-	-	8.4817**
Income	-	-	-	-	-6.3775**	2.4975*	-3.4007**
Hotels rooms	0.1550*	-	-	0.5382***	-	-	-
Pop_60+	-	-2.0317*	-	-1.5903***	-	-	-2.0244**
Density	-	-	-	-	-1.0262***	-	-
Sunshine	-	-	-1.0786**	-1.6779***	1.6786**	-	-
Inter-communal_Rate	-0.2796**	-	-	-	-	-	-
Numb_IS	0.0621**	-	-	-	-	-	-
Constant	-	9.7933	9.3510**	18.8654***	61.4855**	-48.2621	23.6761*
N	288	384	322	310	50	384	269
N_g	96	96	-	-	-	96	-
r2_w	0.6257	0.4308	-	-	-	0.1870	-

[18] Insignificant variables are deleted to save space.

r2_b	0.0457	0.0019	-	-	-	0.3787	-
sigma_u	1.1694	8.3229	-	-	-	22.2986	-
sigma_e	0.0379	0.1935	1.0433	2.6114	1.1478	0.5351	1.3638
Rho	0.9989	0.9995	0.1681	-1.0000	-1.0000	0.9994	-0.3878
Stock and Yogo test[a]	0.0000	-	-	-	-	-	-
Hausman[b] specification test	0,0215	0,0007	-	-	-	0,0000	-
Hausman[b] endogeneity test	0,000	0,1252	-	-	-	0,0628	-
MI Error[c]	0.2328 (0.8159)	0.7975 (0.4252)	- -	- -	- -	0.5183 (0.6043)	- -
RLM Error[c]	0.4815 (0.4878)	0.8684 (0.3514)	- -	- -	- -	0.2177 (0.6408)	- -
RLM Lag[c]	0.0052 (0.9425)	1.2546 (0.2627)	- -	- -	- -	0.0005 (0.9817)	- -
LM SAC[c]	0.6539 (0.7211)	2.1513 (0.3411)	- -	- -	- -	0.2197 (0.8960)	- -

a: p-value and H0: Instruments are weak b: probability, c: p-value in parentheses, -: insignificant, * $p < 0.10$, ** $p < 0.05$, *** $p < .0$

5. Conclusion and policy implications

Using original data at community level and correcting for endogenous local incentive tax and endogenous local government's decision about MSW management technology choices, this study complements the empirical literature on the effectiveness of policies designed to reduce MSW and increase recycling. We have learned that local government's choices do matter. Both the choice of incentive taxes and the choice of MSW management technologies appear to be thoughtful actions depending on national incentives, household characteristics and MSW organization in the local jurisdiction.

Our main conclusion is that "upstream" and "downstream" instruments of the French pricing system are complementary with a superiority of the user fee programs (REOM tax). Although all municipalities with user fee programs already established a curbside recycling program, households did not recycle voluntarily. That means French households are predominantly not environmentally friendly and they need direct incentives to reduce waste and to substantially recycle. Indeed, EPR programs have been implemented since 1990, while user fee programs actually began in the 2000's (ADEME, 2014-a). We also learned from this study that the French MSW pricing system could be improved. Estimation results show that the interaction between REOM tax and EPR programs has perverse effects. First, municipalities that implement REOM tax and EPR programs have a greater tendency to select the dumping technology (coefficient of REOM_EPR in Table 4). Second, households in these municipalities have demanded more MSW collection and have sent more MSW to incineration without energy recovery (coefficient of REOM_EPR in **Table 5**). This suggests that preventive and substitution effects are minor in these municipalities. Glachant (2005) gives an explanation of this finding and proves that in the French case, where there are one local incentive tax (REOM) and one national incentive tax (EPR programs), the eco-participation of firms and the REOM tax are too low to efficiently match together.

References

ADEME. (2014). *Les filières de la Responsabilité Elargie du Producteur : Panorama 2013*. Collection Repères, ISBN 978-2-35838-858-0.

ADEME. (2014-a). *Chiffres-clés déchets*.

Allers, M. A., & Hoeben, C. (2010). Effects of Unit-Based Garbage Pricing: A Differences-in-Differences Approach. *Environ Resource Econ 45*, 405–428; DOI 10.1007/s10640-009-9320-6.

Calcott, P., & Walls, M. (2000). Can downstream waste disposal policies encourage upstream "Design for Environment"? *American Economic Review Papers and Proceedings, 90*, 233-237.

Callan, S. J., & Thomas, J. M. (2006). Analyzing demand for disposal and recycling services: a sustems approch. *Eastern Economic Journal, 32*.

Cassette, A., & Paty, S. (2006). La concurrence fiscale entre communes est-elle plus intense en milieu urbain qu'en milieu rural ? *Cahiers d'économie et sociologie rurales, n° 78*.

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

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

Dubois, M., & Eyckmans, J. (2014). Efficient Waste Management Policies and Strategic Behavior with Open Borders. *Environ Resource Econ*, DOI 10.1007/s10640-014-9851-3.

Feld, L., Josselin, J.-M., & Rocaboy, Y. (2002). Le mimétisme fiscal: une application aux régions françaises. *Economie & prévision/5 n°156*, 43-49.

Ferrara, I., & Missios, P. (2005). Recycling and Waste Diversion Effectiveness: Evidence from Canada. *Environmental & Resource Economics 30*, 221–238.

Fleckinger, P., & Glachant, M. (2010). The organization of extended produce rresponsibility in waste policy with product differentiation. *Journal of Environmental Economics and Management, 59*, 57-66.

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

Fullerton, D., & Wu, W. (1998). Policies for green design. *Journal of environmental economics and management, 36*, 131-148.

Glachant, M. (2005). La politique nationale de tarification du service des déchets ménagers en présence de politiques municipales hétérogènes. *Economie & prévision*, 85-100.

Heckman, J. (1979). Sample selection bias as specification error. *Econometrica, Vol. 47, N°1* , 153–161.

Jayet, H., Paty, S., & Pentel, A. (2002). Existe-t-il des interactions fiscales stratégiques entre les collectivités locales? *Economie & prévision/3 n°154*, 95-105.

Kinnaman, T. C. (2006). Policy watch: Examining the Justification for Residential Recycling. *Journal of Economic Perspectives, 20*, 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 48*, 419-442.

Kipperberg, G. (2007). A Comparison of Household Recycling Behaviors in Norway and the United States. *Environmental & Resource Economics*, 215–235, DOI 10.1007/s10640-006-9019-x.

Kuo, Y.-L., & Perrings, C. (2010). Wasting Time? Recycling Incentives in Urban Taiwan and Japan. *Environ Resource Econ 47*, 423-437; DOI 10.1007/s10640-010-9386-1.

Lakhan, C. (2015). Evaluating the effects of unit based waste disposal schemes on the thecollection of household recyclables in Ontario, Canada. *Resources, Conservation and Recycling 95* , 38–45.

Leprince, M., Madiès, T., & Paty, S. (2007). Business tax interactions among local governments: an empirical analysis of the frech case. *Journal of Reginal Science, VOL. 47, NO. 3*, 603–621.

Leprince, M., Paty, S., & Reulier, E. (2005). Choix d'imposition et interactions spatiales entre collectivités locales. Un test sur les départements français. *Recherches économiques de Louvain/1 (Vol. 71)*, 67-93.

Madiès, T., Paty, S., & Rocaboy, Y. (2005). Les stratégies fiscales des collectivités locales: De la théorie à la pratique. *Revue de l'OFCE 94*, 284-311.

Saphores, J.-D. M., & Nixon, H. (2014). How effective are current household recycling policies? Results from froma national survey of U.S. households. *Resources, Conservation and Recycling 92* , 1–10.

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.

Stock, J. H., & Yogo, M. (2005). Testing for weak instruments in linear IV regression. In identification and inference for econometric models: Essays in honor of Thomas Rothenberg, ed. D. W. K Andrews and J. H. Stock, 80-108. *Cambridge University Press*.

Suwa, T., & Usui, T. (2007). Estimation of garbage reduction and recycling promotion under the Containers and Packaging Recycling Law and garbage pricing. *Environmental Economics and Policy Studies*, 239-254, DOl 10.1007/s10018-007-0128-8.

Usui, T., & Takeuchi, K. (2014). Evaluating Unit-Based Pricing of Residential Solid Waste: A Panel Data Analysis. *Environ Resource Econ*, 245-271, DOI 10.1007/s10640-013-9702-7.

Yang, H.-L., & Innes, R. (2007). Economic Incentives and Residential Waste Management in Taiwan: An Empirical Investigation. *Environmental & Resource Economics 37*, 489–519, DOI 10.1007/s10640-006-9040-0.