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Do Not Trash the Incentive! Monetary Incentives and Waste Sorting

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DO NOT TRASH THE INCENTIVE!
MONETARY INCENTIVES AND WASTE SORTING

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This paper examines whether monetary incentives are an effective tool for increasing domestic waste sorting. We exploit the exogenous variation in the pricing systems experienced during the 1999–2008 decade by the 95 municipalities in the district of Treviso (Italy). We estimate with a panel analysis that pay-as-you-throw (PAYT) incentive-based schemes increase by 12.2% the ratio of sorted to total waste. This increase reflects a change in the behavior of households, who keep unaltered the production of total waste but sort it to a larger extent. In addition, we show that several factors that may discourage local administrators from adopting PAYT – illegal dumping and higher cost of management – are not important at the aggregate level. Hence, our results support the use of PAYT as an effective tool to increase waste sorting.

Keywords: Incentives, waste management, PAYT.

JEL codes: D01, D78, Q53.

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1. Introduction

In many ways economics is the study of incentives and their optimal design. An incentive is anything (monetary or nonmonetary) that motivates a person to undertake a particular action or choose one alternative instead of another. Incentives are widely used in the workplace to align employees' and organization's goals, but also in many other contexts and with many different applications. For instance, incentives have been designed to promote healthy habits such as attending an exercise facility (Charness and Gneezy, 2009) or safe driving (Dionne et al., 2010). Incentives are also used to reduce harmful behavior such as cigarette smoking (Gruber and Köszegi, 2001), alcohol consumption (Cook and Tauchen, 1982), and junk food eating (Jacobson and Brownell, 2000).

The goal of this paper is to study the effectiveness of monetary incentives within the controversial environment of domestic waste disposal. Specifically, we aim to understand if monetary incentives can be used to increase the sorted waste ratio[1] and therefore reduce the amount of (unsorted) waste produced. Waste disposal is challenging: available options are to bury waste in landfills or burn it in incinerators. However, landfills can store only a small part of the waste we produce, and they are often perceived as dangerous to the health of citizens (Kinnaman and Fullerton, 2000). Incinerators, for their part, are expensive and their consequences on health and the environment seem controversial (British Society for Ecological Medicine, 2005; Health Protection Agency, 2005). A viable solution is to sort and then recycle domestic waste. However, sorting waste is not a pleasant activity: it requires considerable effort, a lot of time and attention. The question is if – and eventually how – monetary incentives can help us to promote this desired behavior.

Historically, in Western countries households used to drop off all of their mixed waste in special bins placed along the streets, and they were charged a flat fee related to parameters such as the house size and/or the number of household members. Local administrators progressively started promoting increasingly more accurate collection of sorted waste in the streets. More recently, many municipalities have chosen to collect sorted waste door to door (DtD). DtD can be seen as a nonmonetary incentive, since it makes the sorting of waste easier for the users, who do not need to carry it and drop it off along the streets, and it imposes constraints on the volume and frequency of waste collection. In addition, some local

[1] The sorted waste ratio is the amount of sorted waste compared to the total amount of waste produced. Because sorted waste is potentially recyclable, many authors use the term *recycling ratio* instead of sorted waste ratio (Kinnaman, 2006).

administrators throughout the world abandoned the flat fee in favor of a per-unit pricing, the so called “pay-as-you-throw” (PAYT) system. This pricing system is designed to encourage waste sorting by linking the fee to the amount of residual (unsorted) waste actually produced. The PAYT pricing system is generally coupled with a DtD collection system because it is otherwise difficult to detect incorrect behavior (Kinnaman, 2006). Previous research has determined the effectiveness of the *joint* adoption of DtD and PAYT: studies show that the sorted waste ratio (the ratio between sorted and total waste) increases by 25% to 35% under the two programs (see Miranda et al., 1994; Allers and Hoeben, 2010; and the literature review in Kinnaman, 2006).

Although many municipalities switched from drop-off to DtD collection, only a few adopted PAYT. The reason is that there is wide debate in the literature on the overall effectiveness of introducing this monetary incentive (see, e.g., Skumatz, 2008, and Kinnaman, 2006). In particular, policy makers have three main concerns on the adoption of PAYT. First, the introduction of PAYT may be ineffective if users see it as a *price* for producing unsorted waste, and therefore crowd out their intrinsic motivation to sort diligently (see, e.g., Ariely et al., 2009; Benabou and Tirole, 2003; Gneezy and Rustichini, 2000). Second, the presence of PAYT may foster illegal dumping since users may want to “hide” part of their waste to pay a lower fee (see, e.g., Fullerton and Kinnaman, 1996). Third, policy makers may not like the higher management costs of the PAYT system that result from the need for more expensive equipment, the higher cost of monitoring inappropriate behavior, etc.

In this paper we estimate the effect of the introduction of PAYT on sorting waste in the first year and over time. Moreover we analyze whether the concerns presented above are relevant or not. Going into more detail, we aim to (1) disentangle the net effect of PAYT from the effect of DtD on the sorted waste ratio; (2) measure the relevance of illegal dumping, that is, the fraction of waste “hidden” by the municipalities adopting PAYT; and (3) compare the average cost to users in municipalities that adopt a flat-fee system versus those municipalities adopting PAYT.

To this end, we collected data on waste disposal for the 1999–2008 decade for 95 municipalities in the district of Treviso, Italy. This dataset is unique for at least three reasons. First, prior to the period we considered, a law divided the district in three geographic subareas, each managed by a different consortium. Therefore, nearly all of the municipalities in our sample were not directly responsible for the decisions on waste management; they followed the policy of the consortia. This exogenous intervention removes the potential endogeneity problems that are usually present in these studies. Second, our sample includes wide heterogeneity of policies; 94 of the 95 municipalities in 1999 were adopting drop-off collection and flat-fee pricing, whereas in 2008, 41 were adopting DtD and flat-fee pricing, and 53 DtD and PAYT pricing. Third, the panel structure of our dataset allows us to control for exogenous features such as an increasing concern for the environment, and to isolate potential "learning effects" of incentives over the years.

We then merged this dataset with data on the demographic characteristics of each municipality, provided by the Italian National Institute of Statistics (Istat), and further elaborated by the statistical unit of the Veneto region. The resulting dataset allowed us to control for all of the different characteristics of these municipalities and for all of the characteristics of their inhabitants and to estimate the effect of these variables on the sorted waste ratio.

Our results show that well-designed monetary incentives are effective even in the controversial environment of domestic waste disposal. We found that the introduction of a PAYT system had a significant and positive net effect of 12.2% on the sorted waste ratio, which is complementary to (yet not a substitute for) the positive effect induced by DtD, 18.1%. In addition, the ratio increases by an additional 3.7% when one confining municipality implements PAYT. At the same time, we are able to exclude illegal dumping as a relevant issue at the aggregate level. The "hiding" effect of PAYT municipalities in confining municipalities with drop-off collection is small and weakly significant. Moreover, even if a PAYT program has higher management costs compared to flat-fee programs, we observed that the average household fees were almost identical. This means that higher costs were compensated for by a reduction in the amount of unsorted waste and, therefore, its disposal cost. Finally, we want to point out that PAYT is designed to increase sorting and not to reduce the total amount of waste. Our analysis shows that this is indeed what happens: the sorted waste ratio increases but there is no reduction in the amount of total waste. This finding implies that users improve their attention, ability, and consciousness about sorting, but they do not produce less waste.

The remainder of the paper is organized as follows. Section 2 describes the data source, the history, and the characteristics of the municipalities in our dataset. Section 3 describes our empirical strategy, and its results are reported in Section 4. Section 5 discusses some open questions and presents the direction of our future research. Two final appendices provide further details about our data and on the waste management programs in these municipalities.

2. The Data

We collected data between 1999 and 2008 on the amount of waste produced in a given year in the municipalities of the small but highly populated district of Treviso, in northeastern Italy; further details on the district are given in Section A.1 of Appendix A. This gives us a total of 10 annual time series observations for each of the 95 municipalities in the district.[2] During the past decades the municipalities in this district showed marked progress in terms of sorted solid waste collection, moving from an average sorted waste ratio (the ratio between the amount of sorted waste and total waste) of 35.4% in 1999 to a ratio of 68.5% in 2008 (Arpav, 2000, 2009). The sorted waste ratio in 2008 was outstanding compared with the national average (30.6%) and the regional average (53.9%). Many of these municipalities are among the best practitioners of waste management in Italy (Legambiente, 2009) as well as Europe, exceeding by far the targets of differentiation set by the European Commission (Eurostat, 2010). This success is likely related to the change in waste management policies that arose over the decade we consider in the analysis.

The building blocks of our dataset are two: first, yearly data on sorted and residual waste production at the municipal level provided by the Regional Agency for Environmental Prevention and Protection of Veneto (Arpav)[3]; second, raw data on the demographic characteristics of each municipality, provided by the Italian National Institute of Statistics (Istat), and further elaborated on by the statistical unit of the Veneto region.

As described in Section A.2 of Appendix A, in the late 1980s a regional (frame) law identified three geographic areas within the district and encouraged the creation of independent, nonprofit consortia of municipalities within each area. Each municipality was allowed, though not forced, to join the consortium in its area. At the end of 2008, 91 municipalities out of 95 joined the consortium operating in their area; 4 municipalities remained independent, essentially for structural or geographic reasons. Further details are given in Section A.2. Our main analysis, shown in Sections 4.1 and 4.2, is based on 10 annual observations for all 95 municipalities. In a robustness check, reported in Section 4.3, we repeat the analysis based on a smaller sample, including only the municipalities belonging to a consortium, and only in the years following adhesion.

After joining a consortium, each municipality delegates all decisions regarding waste management to the board of its consortium. Importantly, over the period during which our

[2] We ignore data before 1999 because municipalities were still in the process of organizing their waste management and, therefore, the quality and reliability of the data were rather poor.

[3] Information about Arpav may be found at http://www.arpa.veneto.it/inglese/htm/chi_e_arpav.asp. We double-checked these data with those available to the consortia.

investigation took place, the boards of the consortia implemented different policies along two dimensions: the collection system (drop-off as opposed to DtD) and the pricing system (flat fee as opposed to PAYT). We exploit this exogenous variation in the policies to disentangle the net effect of the introduction of PAYT. This environment resembles a quasi-natural experiment, because the collection and pricing systems are imposed on the municipality by the consortium and, hence, are not chosen directly by the municipality (see Section A.2 for more details).

Appendix B provides details on the collection and pricing systems. In particular, the two pricing systems can be described by the following equations. The flat fee is proportional to the user's house surface and/or the number of household members:

$$flat\ fee = \phi_0 \times (No.\ of\ houses\ square\ meters) + \phi_1 \times (No.\ of\ household\ members) \qquad (1)$$

where ϕ_0 and ϕ_1 are the costs, respectively, per square meter and per household member.[4] In this system there is no direct link between the actual waste production and the fee paid, even though the house's square meters and the number of household members seem reasonable proxies for the production of waste. However, given a particular house and household size, this scheme provides no incentive to sort waste.

In contrast, the PAYT's main feature consists of establishing a direct link between costs and users' sorting behaviors. Many PAYT schemes are made of a fixed part that is identical for each single user, and a variable part that depends on the amount of the residual waste produced:

$$PAYT = \theta_0 + \theta_1 \times (No.\ of\ emptyings\ of\ residual\ waste\ bin) \qquad (2)$$

where θ_0 and θ_1 are, respectively, the fixed cost and the cost per residual waste bin emptied.[5] According to this equation, accumulating residual waste is relatively costlier than accumulating sorted waste. In addition, to prevent users from sorting inappropriately and lowering the amount of unsorted waste, a system of monitoring and sanctioning is usually applied.[6]

Figure 1 shows the dynamics of collection and pricing systems in our dataset. In 1999, 94 out of 95 municipalities in the district were implementing drop-off collection systems with flat-fee pricing. (Only one municipality, Vedelago, was implementing DtD with a flat fee.)

[4] The parameters ϕ_0 varied as reported in Table B.1 of Appendix B.

[5] In 2008 the average fixed cost θ_0 was equal to 82.38 euros, and the average variable cost θ_1 was equal to 10.39 euros per emptied waste bin. The number of emptyings varied between five and eight per year (depending on the numbers of household members), as reported us by the management staff of Consortium Priula.

[6] The system in the district operates jointly with the local municipal authorities. More than 2,000 inspections were conducted in the district of Treviso in 2004, as reported us by the management staff of Consortium Priula.

Since 2000, they gradually started changing the policy; as of 2008, 41 out of 95 municipalities were implementing DtD with flat-fee pricing, 53 were implementing DtD with PAYT pricing, and just one municipality (Treviso) was still adopting drop-off with flat-fee pricing. Hence, our dataset includes municipalities with three types of waste management system: drop-off with flat fee, DtD with flat fee, and DtD with PAYT. We observed no municipalities implementing drop-off and PAYT. In fact, systems with drop-off and PAYT are rarely seen in the world (Reschovsky and Stone, 1994; Kinnaman, 2006), because such a system makes it extremely difficult to detect users' incorrect behavior. Appendix B reports more details on the historical evolution of pricing and collection systems in the district.

FIGURE 1 ABOUT HERE

Figure 2 shows the dynamics of the sorted waste ratio in our sample. We observe an increasing trend in the ratio with all of the waste management systems, even the one with no incentives at all (the system with drop-off collection and flat fee). The sorted waste ratio, however, is steadily higher in the subsample of municipalities with DtD and PAYT.

FIGURE 2 ABOUT HERE

3. Empirical Strategy

Our empirical strategy is designed to verify the effect of the introduction of a monetary incentive (PAYT) on the sorted waste ratio, and to understand if this effect is complementary to, rather than a substitute for, the one associated with the DtD program.

The analysis is based on the following model, where i denotes the municipality and t time:

$$Y_{it} = \beta_0 + P_{it}'\beta_1 + C_{it}'\beta_2 + D_{it}'\beta_3 + T_{it}'\beta_4 + \mu_i + \varepsilon_{it} \qquad (3)$$

where β_0, β_1, β_2, β_3, and β_4 are coefficients to be estimated; μ_i represents municipality effects; and ε_{it} is the error term. The dependent variable Y_{it} is the logarithm of the sorted waste ratio (the ratio between sorted and total waste) in Section 4.1, and the logarithm of per capita (sorted, total) waste in kilograms in Section 4.2. The specification includes explanatory variables that can be grouped in four sets $(P_{it}, C_{it}, D_{it}, T_{it})$, as discussed below.

Estimation is performed by means of a fixed-effects panel regression model. We chose this type of model for several reasons. First, it provides consistent estimates even if the specification omits important time-invariant variables on the structural characteristics of the municipalities. In general, the coefficients μ_i capture all of the (fixed) heterogeneity among the municipalities that is not explained with the other variables in the specification, such as municipality surface or intrinsic efficiency of the public administration. Second, we prefer this model for its statistical properties, since it turns out to describe the data generally better than pooled regression models (without municipality effects) and random-effects panel models (where municipality effects are not absorbed in the error term); results of these statistical tests are reported in the bottom parts of Tables 2 and 3 in Section 4.

Below we describe the explanatory variables in Eq. (3) and why we take them into account. Table 1 reports descriptive statistics of the key variables in the dataset.

Policy Variables

Set P_{it} takes into account variations in waste management policies. We set the dummy variable "PAYT" equal to 1 when the municipality is implementing PAYT, and the dummy variable "DtD" equal to 1 when the municipality is implementing DtD. The two variables capture the net effect of either policy being active. In particular, we are interested in the sign of the coefficient on PAYT. If it is significantly positive, then the monetary incentive represented by PAYT is complementary to the nonmonetary one represented by DtD. If the coefficient is not significant, we interpreted it as a signal that the monetary incentive is not effective. Finally, if it is significantly negative, the monetary incentive brought by PAYT is actually detrimental and it goes against the nonmonetary incentive represented by DtD

In addition, we include variables that capture a potential "learning process" in the application of PAYT or DtD policies. What we mean is that users may need time to become acquainted with the incentive scheme in the PAYT payment formula, or with the proper use of the different waste bins provided by a DtD system. Ignoring this might be misleading and could bias our estimates. We assumed that this learning process follows a linear trend,[7] and we created the corresponding variables as follows: If a PAYT program started in year t^*, the trend variable for PAYT at year t is defined as $\max\left\{0, PAYT \times \left(t - t^*\right)\right\}$; an equivalent definition applies for DtD. Thus each variable captures the effect of having a PAYT or DtD program active for one additional year.

[7] We treat this as a linear trend because PAYT and DtD programs in our sample started just a few years ago, and for this reason we were not able to capture further degree polynomials.

Control Variables

Set C_{it} includes control variables that captured the potential "emulation" effects of confining municipalities (the number of confining municipalities implementing PAYT, the number of confining municipalities implementing DtD) and one variable that captures potential "hiding" effects (the number of confining municipalities not implementing DtD, interacting with the dummy variable on PAYT).

We consider these variables for the following two reasons: First, households may be more willing to sort waste if they see that their peers in neighbor municipalities are already doing so (the "emulation" effect). Second, households living in municipalities following a PAYT program may choose to throw away their residual waste in nearby municipalities that are still under a program with drop-off collection so that they can pay lower fees (the "hiding" effect).[8] Illegal dumping is indeed one of the main concerns for introducing PAYT (Fullerton and Kinnaman, 1996).

Demographic Variables

Set D_{it} takes into account variations in the demographic composition of the municipality: the logarithm of the number of inhabitants, the percentage in the population of children ages 14 or younger, the percentage in the population of individuals ages 65 or older, and the percentage in the population of non-native residents.

We include these variables for three reasons: First, the number of inhabitants affects the size of the municipality and how it evolves over the years. We expect larger municipalities with more inhabitants to be structurally different than smaller municipalities with fewer inhabitants, which should have implications on the effectiveness of changing the sorted waste ratio. Second, we expect the sorted waste ratio to change in municipalities with a higher percentage of young people (who are often the target group of media campaigns on environmental issues) and elderly people (who usually do not work and have more time to sort waste efficiently). Finally, we may expect that non-native residents are more reluctant than native ones to follow the prescriptions of PAYT and DtD programs, for several reasons (culture, language barriers, etc.).

Time Variables

Set T_{it} includes variables meant to capture the time trend: one macroeconomic indicator (the annual unemployment rate in the district, taken from Istat) and a set of year dummy variables

[8] Whenever we refer to the "hiding" effect, we actually mean the effect of "garbage tourism."

(the base is represented by the years in the middle of the sample, 2003 and 2004). The idea is that at the beginning of the sample there was less concern for the environment than in the following years, as a result of, for example, massive media campaigns. We expect this increase in concern to make the sorted waste ratio rise anyway, even if no change is made in the pricing or collection mechanism.

Identification of the year dummy variables together with the variables on the "learning effect" of PAYT and DtD is possible in our dataset because in any given year we observe municipalities without PAYT/DtD, municipalities that just started PAYT/DtD, and municipalities that started PAYT/DtD some years earlier.

TABLE 1 ABOUT HERE

4. Results

Table 2 shows our main results of the effects of PAYT and DtD programs on waste sorting. Section 4.1 discusses the effects on the sorted waste ratio, while Section 4.2 comments on the effects on the amount of sorted and total waste. Finally, Section 4.3 discusses a robustness check with a subsample of observations; the corresponding results are shown in Table 3.

4.1. Effects on the Sorted Waste Ratio

The first column of Table 2 shows a significantly positive effect for both PAYT (12.2%) and DtD (18.1%).[9] This finding supports the hypothesis that the monetary incentive of PAYT is *complementary* to the nonmonetary incentive of DtD. Moreover, there is a significantly positive "learning effect" of incentives, as captured by the linear trend variable associated with the PAYT option (1.8%). Our interpretation is that users need time to understand and fully exploit the monetary incentive represented by PAYT. Overall, this regression then suggests that the sorted waste ratio increases by 12.2% whenever PAYT is active and by 1.8% in every further year after PAYT implementation. In contrast we find that the sorted waste ratio rises by 18.1% with DtD and that it carries no "learning" effect.

We find a positive emulation effect in the confining municipalities implementing PAYT (the coefficient is estimated at 3.7%); the sorted waste ratio rises by 3.7%, even in the absence of incentives in the waste management system, just because one nearby municipality

[9] The sum of the two effects, 30.3%, is in line with previous works that do not distinguish between the effects of DtD and PAYT (see the results reported in Kinnaman, 2006).

implements PAYT. In our view, users look at the behavior of users in nearby municipalities and tend to replicate it in their municipality.

Interestingly, there is weak evidence (at 10%) of a hiding effect of PAYT municipalities in confining municipalities with drop-off collection; the coefficient we estimate indicates that the sorted waste ratio increases by 3.3% in municipalities with PAYT for any confining municipality with drop-off collection. We believe this may happen because users choose to throw their residual waste in the public bins of nearby municipalities. However, the evidence is not statistically strong and the estimated aggregate effect of 3.3% is small compared to the effect of the policy itself, 12.2%.

All of the preceding findings are net of the effects on demographic and time variables; in particular, such variables as the number of inhabitants, the percentage of residents who are children, and time turn out to be significant in all of our models. Including the coefficients of the year dummy variables seems especially relevant, because it suggests—not surprisingly—that the sorted waste ratio tends to increase anyway over the years.

As a final remark, we want to stress that with PAYT we find an increase in the sorted waste ratio (12.2%), and this increase has virtually no cost to the households. As reported us by the management staff of Priula consortium, households paid 140.11 euros with PAYT and 140.84 euros without PAYT on average in 2008. This is because in the municipalities where PAYT is active, households have a strong incentive to reduce the production of unsorted waste. This evidence contrasts with the potential concern that PAYT carries high user costs, and it reinforces our conclusion about the effectiveness of PAYT programs.

TABLE 2 ABOUT HERE

4.2. Components of the Sorted Waste Ratio

We then look more closely at the two aggregate components of the sorted waste ratio: sorted waste and total (sorted plus residual) waste. Columns (2) and (3) of Table 2 show the estimates of the model in Eq. (3), where the dependent variable is now the logarithm of per capita sorted waste in kilograms (column 2) and the logarithm of per capita total waste in kilograms (column 3).

We chose to look at the determinants of these variables because the sorted waste ratio may increase as a result of an increase in sorted waste, a reduction in total waste, or both. From the regression in column (1), we cannot say anything on this issue. However, knowing this is important because it provides more precise information on how the PAYT incentive works. We expect that, by increasing the relative cost of producing residual waste, PAYT makes it more convenient to increase sorted waste. In contrast, it should have no implications on the production of total waste. Clearly, this will happen provided that the monetary incentive works properly.

The regression output supports our hypothesis. Indeed, we find for PAYT a significantly positive effect on per capita sorted waste (which rises by 9.6%; see column 2), and an insignificant effect on per capita total waste (the coefficient –0.026 is statistically equal to zero; see column 3). In addition, we find that the emulation effect of nearby municipalities with PAYT is significant only for sorted waste (4.3% for each nearby municipality, see column 2).

Column (2) also shows weak evidence (at 10%) that the production of total waste falls by a small amount (1.7%) when PAYT programs are active and there are confining municipalities with drop-off collection. Figure 3 supports this ”hiding effect” graphically, by comparing the percentage annual growth in per capita total waste of the municipality of Treviso – the only one maintaining drop-off collection and flat fee systems over all our sample period – with the average growth of municipalities implementing DtD and PAYT systems. In both cases we take as base year the one where the first municipalities started a PAYT program, 2002. From the figure it is clear that per capita total waste falls in municipalities with PAYT, while it rises in Treviso; in 2008, an average inhabitant of Treviso produced 14.39% more total waste than in 2002, as opposed to an average inhabitant of a municipality with PAYT, who produced 5.92% less total waste. It should be stressed, though, that the hiding effect we estimate in the regression of column (3), 1.7%, is small, as it was the effect we found in column (1), 3.3%. In addition, there is no statistical evidence of a significantly different size of per capita total waste between 2001 and 2003 in the municipalities with DtD and PAYT systems (t-test: -0.985, p-value: 0.329).

FIGURE 3 ABOUT HERE

In contrast, we find that DtD increases per capita sorted waste (which rises by 7.6%; see column 2) and it also reduces per capita total waste (by 10.5%; see column 3). This effect supports the view that DtD is a form of nonmonetary incentive aimed at increasing sorted waste by eliminating the time costs of carrying waste to the streets, and reducing total waste by imposing constraints to the amount of waste production (e.g., providing a given size of personal trash bin and setting a given frequency for waste collection).

Our results suggest that monetary incentives are an effective tool in fostering the sorting behavior at the municipal level, and they seem to be a potential instrument for reaching future goals in waste management, mainly the reduction of per capita total waste (European Union, 2008). For example, applying monetary incentives not only to the unsorted waste but also to specific fractions of sorted waste (plastic, paper, etc.) may have interesting effects on the reduction of the total waste produced and on the economic sustainability of DtD collection.

4.3. Robustness Checks

We conclude the section by reporting on the outcome of a robustness check of our results. In Section 2 we explained that municipalities in our dataset may delegate to a consortium all of the decisions regarding the waste management policies. The exogenous intervention of a consortium removes potential endogeneity problems, in that policy makers and municipalities with more pronounced concern for the environment – that we may expect to exhibit intrinsically higher sorted waste ratios – opt for an incentive-based waste management system. In our dataset nearly all of the municipalities (91 out of 95) delegate the decisions to a consortium, and they do so generally early (84% of the municipalities were already members of a consortium in 1999; see Section A.2 in Appendix A). However, we still include observations where municipalities are free to choose their own policy.

For this purpose we replicate here our analysis on a smaller sample, by excluding all of the observations where the municipality is free to choose its own management system. This means that we ignore the four municipalities currently not members of a consortium, as well as the observations regarding the remaining municipalities prior to joining a consortium. Our final dataset then consists of 865 observations on 91 municipalities (around 91% of the original sample), in which the choice of the waste management policy is always set exogenously.

The output from this analysis is reported in Table 3. Our previous results are largely confirmed, both qualitatively and quantitatively. In particular, we find for PAYT an effect on the sorted waste ratio of 11.2% (instead of 12.2% as in the benchmark), an effect on the amount of sorted waste of 8.9% (as opposed to 9.6%), and no effect on the amount of total waste. The only differences with the benchmark case concern column (1) of the table. Indeed we no longer observe either a learning effect of the PAYT incentive over the years or a hiding effect of PAYT on nearby municipalities. In the latter case, however, evidence was only weak in the benchmark analysis.

TABLE 3 ABOUT HERE

5. Discussion

We used a unique dataset on waste management in an Italian district to investigate the effect on the sorted waste ratio of the monetary incentive represented by pay-as-you-throw (PAYT) pricing, in combination with the nonmonetary incentive represented by door-to-door (DtD) waste collection. We find evidence that the PAYT incentive has the net effect of increasing the sorted waste ratio by around 12.2% and that it is complementary to the net effect of the DtD incentive (18.1%). In addition, municipalities with a PAYT program increase the amount of per capita sorted waste by 9.6%, but have no bearings on the amount of per capita total waste. Our results were obtained controlling for specific characteristics of the municipalities, and they are robust to different assumptions of the model. Our findings thus confirm that, in aggregate, well-designed monetary incentives are an effective way to promote virtuous behavior and they suggest that decision makers should "not trash monetary incentives."

The analysis in the paper is performed at the municipal level. Future research should take a closer look at individual data, where negative consequences may result from adopting PAYT for particular users. We will focus on three main issues. First, we will dig out cases of illegal dumping and garbage tourism in which users try to "hide" their waste so that they pay less (see, e.g., Fullerton and Kinnaman, 1996). In our analysis we controlled for this effect in aggregate by considering that users living in municipalities with PAYT might carry their waste to confining municipalities that have drop-off collection programs. We find weak evidence of a small effect in support of this view. The use of individual data will tell us if the effect is small or, rather, if the deviating behavior is not widespread.

Second, we will consider the perceived unfairness of PAYT pricing. PAYT is sometimes considered unfair (Batllevell and Hanf, 2008) because citizens do not pay proportionally to their income or wealth. This pricing may create stronger incentives for poorer households to sort waste than richer ones. Data at the individual level will shed light on this issue. Third, we will look at free-riding problems. These may arise when the payment depends on the behavior of many users, as in multiproperty buildings. Understanding who is more likely to be influenced by monetary incentives will help the policy maker to implement a menu of incentives targeted to different segments of users, improving the efficiency and the effectiveness of waste management policies.

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Appendix A. Municipalities and Consortia in the Datasets

In this appendix we describe the municipalities in the district of Treviso (Section A.1), the changes introduced by the regional law on municipal waste management (Section A.2), the three consortia operating in the district (Section A.3), and the history of their waste management policies (Section A.4).

A.1. The District of Treviso

As shown in Figure A.1, the district of Treviso (the darker colored area) is located in northeastern Italy, in the region called Veneto (the lighter colored area).

Figure A.1. The Veneto region (light color) and the district of Treviso (dark color) in Italy.

The district covers an area of 2,477 square kilometers. It is one of the more highly populated Italian districts (879,408 inhabitants in 2008), with a higher population density (355 inhabitants per square kilometer) and a higher rate of population growth (the birth rate is 1.07% and the percentage of legal immigrants is 10.9%[10]). The district is divided into 95 municipalities, almost all of relative small size; only one municipality, Treviso, has 82,206 inhabitants. Twenty-four municipalities have between 10,000 and 50,000 inhabitants; 36 between 5,000 and 10,000; and 34 fewer than 5,000 inhabitants. An average municipality has

[10] Statistics in the appendix are provided by Istat for 2008 (http://demo.istat.it). The birth rate is calculated as the ratio between the number of births in the year and the average population with legal addresses in the district, multiplied by 100.

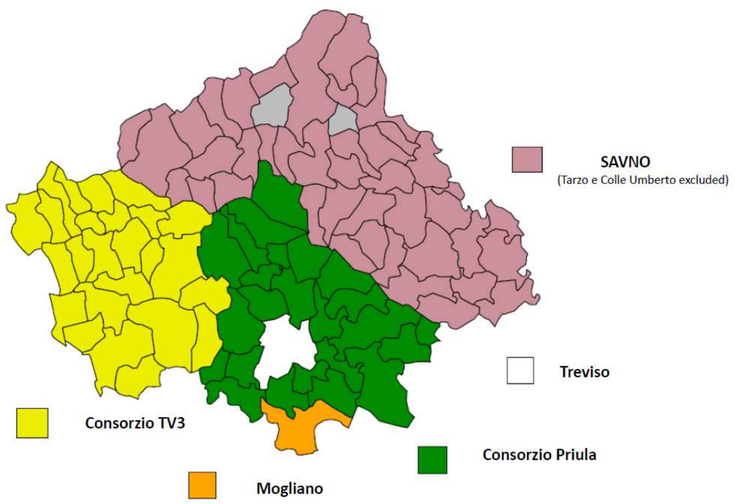
9,303 inhabitants. The area is also relatively rich: the average per capita GDP in 2008 was 30,274 euros, as opposed to the national level of 26,278 euros.

A.2. The Legislative Framework on Waste Management

Italy has four administrative levels (national, regional, provincial/district, and municipal) and each one takes some responsibility for waste management. The national level defines the legislative framework and sets targets coherent with the European Directives. Since 1994 each region has delegated the management of waste to an office called Ambito Territoriale Ottimale (Optimal Territorial Scope, ATO). The office sets targets on landfills for biodegradable municipal waste and separate collection of municipal waste. Districts are responsible for meeting the targets defined by their ATO. To reach the targets, they are free to implement their preferred waste management policies.

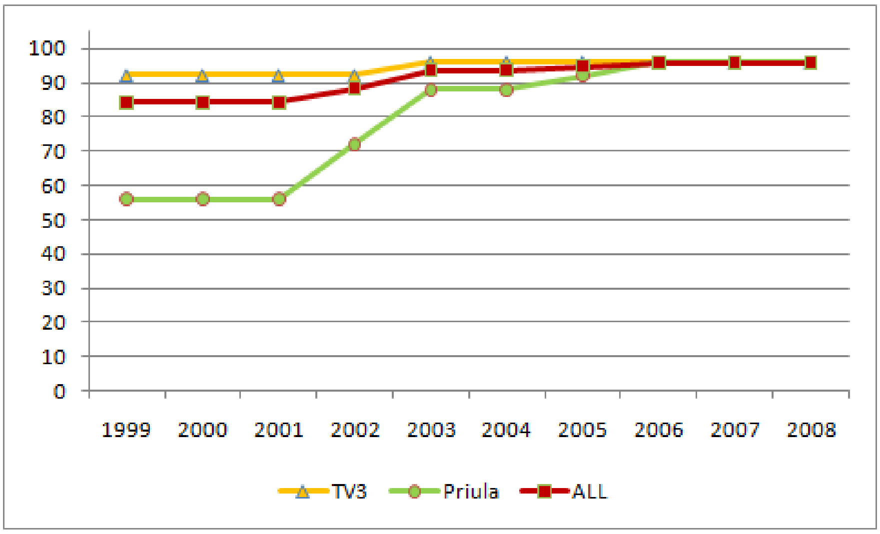
In 1988 the regional plan for the management of urban waste created three territorial units in the Treviso district (TV1, TV2, and TV3), and promoted the birth of a consortium within each territorial unit. The purpose was to centralize decisions regarding waste management policies that, up to that time, had been made by each municipality independently. Consortia set the targets for the sorting rates and costs of the system, and they decide the management policy, in terms of waste collection and billing. After the creation of the three consortia—Priula (in TV2), Savno (in TV1), and TV3—municipalities were encouraged, although not forced, to join the "consortium" managing their territorial unit at any time (see Figure A.2). Once a municipality joins a consortium, it delegates all decisions regarding waste management to the consortium board.

Figure A.2. Consortia and municipalities in the district of Treviso.



Participation was gradual since, according to the regional plan, municipalities were allowed to join the consortium in later years, giving them a chance to let expire any preexisting waste management contracts that had been signed at the municipal level. In a few years, nearly all of the municipalities had joined the consortium in their respective areas, although most of the municipalities (80 out of 95, or 84%) were already linked to a consortium at the beginning of our sample period in 1999 (see Figure A.3). Currently 91 out of the 95 municipalities belong to one consortium. The exceptions are Colle Umberto, Tarzo, Mogliano Veneto, and Treviso, which chose not to adhere, respectively, to Savno (the first two municipalities), Priula, and TV3.[11]

Figure A.3. Trends in the percentage of municipalities joining a consortium.



A.3. The Three Consortia

We now report some facts on the three consortia.

Consortium Priula (http://www.consorziopriula.it), created in 1987, includes 24 municipalities covering an area of 640 square kilometers with around 240,000 inhabitants. In 2008 the municipalities in the consortium reached a sorted waste ratio of 77.06%, gaining first place in national rankings (Legambiente, 2009).

[11] Structural limits (topology and density of the population) prevent Colle Umberto, Tarzo, and Treviso from freely choosing a waste management system. In contrast, Mogliano Veneto follows a waste system in line with the nearby municipalities in the district of Venice.

Consortium TV3 (http://www.tvtre.it), created in 1993, includes 25 municipalities and operates within a territory of 620 square kilometers having around 220,000 inhabitants. In 2008 the municipalities in the consortium reached a sorted waste ratio of 66.56%.

Consortium Savno (http://www.savnoservizi.it), created in 1995, operates in 42 municipalities covering an area of 1,080 square kilometers with around 298,000 inhabitants. In 2008 the municipalities in the consortium reached a sorted waste ratio of 72.53%, gaining third place in national rankings (Legambiente, 2009).

A.4. The Waste Management Systems Adopted by the Consortia

Even though in 1999 nearly all of the municipalities were adopting similar collection methodologies (drop-off) and pricing systems (flat fee), since 2000 they have started to follow different policies. In particular, in 2000, Priula introduced in some municipalities a DtD program paired in the following year with a PAYT program based on the volume of residual nonrecyclable waste produced. The volume is measured by counting the number of times during the year that specific trash bins of residual waste are emptied. These bins have a capacity of 120 liters and are emptied no more often than every 2 weeks. Given this limit on the maximal frequency, a maximum of 26 emptyings per year is possible. In 2008 the average number of emptyings per year was between 5 and 8, depending on the number of household members. In 2008 the yearly cost per household in Priula was approximately 140.11 euros.[12]

Consortium TV3 also started introducing DtD in 2000 but, contrary to Priula, it kept using flat-fee pricing rather than PAYT pricing up to 2008. In the second half of 2009 TV3 also started a PAYT program similar to the one in Priula. We did not use this information in our analysis; we instead stopped our dataset at the end of 2008, because data for 2009 are likely to be biased for the transition from one system to the other (our end-of-year data would provide data on what happened in both the first semester with flat-fee pricing, and the second semester with PAYT). In 2008 the yearly cost per household in TV3 was approximately 140.84 euros.[13]

[12] Pricing follows the PAYT equation, Eq. (2). For flat buildings the variable part of PAYT depends on the volume of the common cart and on the number of times that the cart is emptied divided by the number of flats. On average, in 2008 the fixed cost θ_0 was equal to 82.38 euros, and the variable cost θ_1 was equal to 10.39 euros per emptying. Costs vary over the years. In particular, fixed costs depend on a number of factors, not all strictly related to the collection of waste (such as municipality taxes). Variable costs are instead independently determined by the consortium, and every year they grow with inflation.

[13] Pricing follows the flat-fee formula of Eq. (1). Coefficients differ for each municipality, because they depend on a number of factors such as population size and tourist arrivals. They also depend on the nature of the service (e.g., museums have to pay less than restaurants and private houses have to pay less than shops).

The third consortium, Savno, adopted a DtD collection system but it is more heterogeneous in the pricing systems. In some municipalities the consortium experiments a flat fee, which depends only on each house's surface and/or on the number of family components similar to the one adopted in TV3; in other municipalities the consortium adopts a volume-based pricing system similar to the one in Priula.

Appendix B. Waste Collection and Pricing Systems

In this appendix we describe drop-off and DtD collection systems (Section B.1) and flat-fee and PAYT pricing systems (Section B.2). The photos contained in this Appendix have been kindly provided by the management staff of the consortium Priula.

B.1. Waste Collection Systems

In 1999 nearly all of the municipalities in the district were implementing drop-off collection systems with flat-fee pricing.

Sorting of municipal waste through a drop-off program consists of placing different types of large trash bins for different types of waste (drop-off points) at various places along the street. Users then voluntarily leave their waste (see Figure B.1).

Figure B.1. A drop-off point for sorted and residual waste.

The DtD collection system assigns to each household different small trash bins for different types of waste (see Figure B.2). Waste is sorted and kept in each house until the day on which it is going to be collected, where carts are placed in the streets, just outside each house.

Figure B.2. Carts and bins for organic waste and residual waste in Priula.

Waste is collected periodically according to a calendar that is given to the users, such as the one shown in Figure B.3.

Figure B.3. DtD collection calendar in Priula.

	WHAT	WHEN
	Residual waste	every two weeks
	Food waste	twice a week
	Garden waste	once a week
	Paper and cardboard	every two weeks
	Glass Plastic Cans	every two weeks

The consortia share similar schedules for waste collection and similar carts and bins for waste storage. Moreover, the type of material admitted in each sorted fraction (plastic, paper, glass, etc.) is identical across the consortia as defined in the European Commission Decision 2000/532/CE.

B.2. Waste Pricing Systems

Two alternative pricing systems have been adopted by the consortia in the district of Treviso: a flat fee and PAYT.

The flat-fee price is calculated according to Eq. (1) and it is proportional to the user's house surface and/or the number of household members. Table B.1. shows an example of how the flat fee is calculated in TV3 in the 2008. The table informs on the lower bound of the cost per square meter, ϕ_0, and the lower bound of the variable cost, ϕ_1, which differs with the household size. Each municipality can freely increase the parameters ϕ_0 and ϕ_1 up to a ceiling, depending on such factors as the population of the municipality and the level of tourism.

Table B.1. Flat-Fee Calculation in TV3

Category	Number of Household Members	Fixed Part € per square meter	Variable Part € per user	Cost for an 80-m square meter house	Cost for a 100-square meter house
1	1	0.44	31.11	66.53	75.38
2	2	0.52	62.04	103.66	114.06
3	3	0.58	77.55	124.04	140.17
4	4	0.63	100.81	151.29	163.90
5	5	0.68	124.08	178.54	192.16
6	6 or more	0.72	143.47	201.07	215.41

In contrast to the flat fee, PAYT links costs with users' sorting behavior. Therefore, the implementation of a PAYT pricing system requires the ability to identify who produces what. In Priula and in some municipalities of Savno, identification is possible through an electromagnetic transponder installed in every residual waste bin (see Figure B.4). Every time the cart is placed outside the house for collection, a reader device turns the signal into an alphanumeric code that unequivocally identifies the cart and the owner. This way data on the unsorted waste production for each user are recorder and processed.

In principle, identification of the amount of waste produced is possible not only with DtD collection, but also with drop-off collection. For instance, each household might pass a magnetic card through a card reader device every time it throws waste into a common bin. In that case, it becomes difficult to measure the amount of waste thrown, because people might choose to throw more waste less frequently or mix residual waste with sorted waste. For this reason, cases with PAYT and drop-off collection are rare in practice and limited to few municipalities

Figure B.4 A transponder for the identification of residual waste production.

The calculation of the PAYT fee is made according to Eq. (2) and it is proportional to the number of emptyings of a residual waste cart. Fixed and variable costs vary over the years; Figure B.5 shows the growth of the average PAYT fee per household in Priula from 2001 to 2008 as opposed to price growth (as measured with the CPI index, from Istat). It turns out that the average PAYT fee has decreased over the years in real terms, from 160.25 euros in 2001 to 140.11 euros in 2008 (based on 2008). Notice in particular that the average fee markedly dropped in 2002, that is, in the year when many municipalities in Priula (14 out of 24) moved to a PAYT system.

Figure B.5. The average percentage growth in the household fee in Priula.

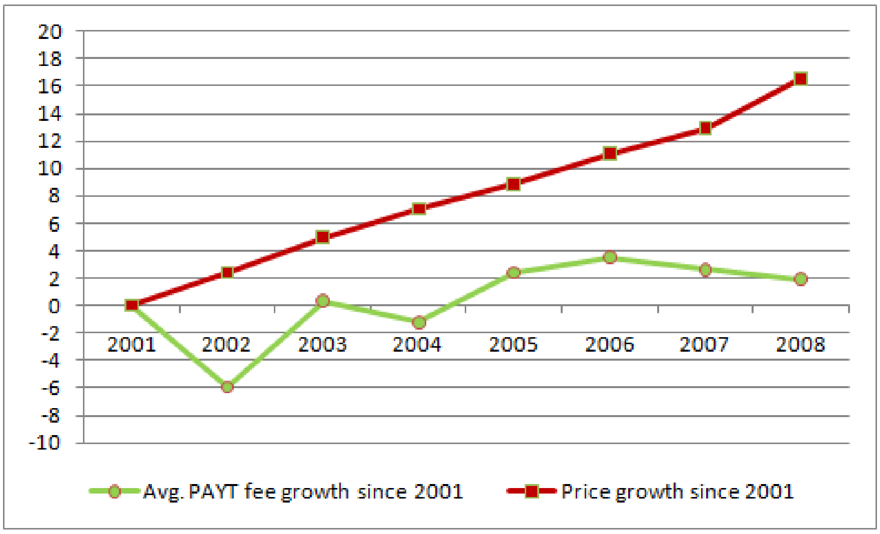


Table 1. Descriptive Statistics: Average Values (from 950 observations in 95 municipalities)

Variable	Source	Median	Average	Std. Dev.	Minimum	Maximum
Sorted waste ratio (%)	Arpav	63.10	58.98	15.40	6.12	84.40
Total waste (ton)	Arpav	1,992.70	3,341.76	5,249.89	298.86	50,244.36
Total waste per capita (kg)	Arpav	328.66	338.94	74.38	171.42	611.20
Residual waste per capita (kg)	Arpav	125.91	140.34	68.58	48.62	440.11
Sorted waste per capita (kg)	Arpav	203.53	198.60	64.56	23.12	385.73
Year of PAYT implementation	Arpav	2004	2003	1.66	2002	2008
PAYT	Arpav	0	0.29	0.45	0	1
Years of PAYT	Arpav	0	0.67	1.42	0	6
Year of DtD implementation	Arpav	2002	2002	1.91	1994	2008
DtD	Arpav	1	0.68	0.47	0	1
Years of DtD	Arpav	1	2.19	2.48	0	14
No. of confining municipalities with PAYT	Arpav	0	1.64	2.13	0	9
No. of confining municipalities with DtD	Arpav	4	3.44	2.30	0	9
No. of confining municipalities without DtD	Arpav	1	1.70	2.10	0	9
No. of inhabitants	Istat	6,227	8,693	10,028	702	83,971
% Children aged 14 or younger	Istat	15.17	15.29	1.82	10.65	24.70
% Adults aged 65 or older	Istat	17.43	17.38	2.88	10.17	25.22
% Non-native residents	Istat	6.93	7.43	3.82	0.83	20.05
% District unemployment rate	Istat	3.40	3.32	0.57	2.50	4.10

Table 2. Effects of Incentives

Dependent Variable (in logs) **Method: Panel OLS with Fixed Effects**	**Sorted Waste Ratio** **(1)**	**Per Capita Sorted Waste** **(2)**	**Per Capita Total Waste** **(3)**
PAYT	0.122***	0.096***	-0.026
	(0.034)	(0.034)	(0.018)
Additional years of PAYT	0.018**	0.012	-0.006
	(0.009)	(0.009)	(0.005)
DtD	0.181***	0.076***	-0.105***
	(0.028)	(0.028)	(0.015)
Additional years of DtD	0.014	-0.012	-0.026***
	(0.010)	(0.010)	(0.005)
No. of confining municipalities with PAYT	0.037***	0.043***	0.006
	(0.008)	(0.008)	(0.004)
No. of confining municipalities with DtD	-0.007	-0.010	-0.003
	(0.008)	(0.008)	(0.004)
PAYT × No. of confining municipalities without DtD	0.033*	0.016	-0.017*
	(0.018)	(0.018)	(0.010)
log(No. of inhabitants)	0.969***	0.149	-0.820***
	(0.279)	(0.275)	(0.146)
% Children aged 14 or younger	0.041**	0.036**	-0.005
	(0.016)	(0.016)	(0.008)
% Adults aged 65 or older	0.001	-0.003	-0.004
	(0.015)	(0.014)	(0.008)
% Non-native residents	-0.013*	-0.013*	-0.000
	(0.007)	(0.007)	(0.004)
% Unemployment rate in the district	-0.053	-0.008	0.046**
	(0.044)	(0.044)	(0.023)
Year 1999	-0.333***	-0.515***	-0.182***
	(0.061)	(0.060)	(0.032)
Year 2000	-0.238***	-0.366***	-0.127***
	(0.059)	(0.058)	(0.031)
Year 2001	-0.186***	-0.263***	-0.077**
	(0.059)	(0.058)	(0.031)
Year 2002	-0.193***	-0.222***	-0.029
	(0.065)	(0.064)	(0.034)
Year 2005	-0.026	0.010	0.036**
	(0.030)	(0.029)	(0.016)
Year 2006	-0.067	0.062	0.129***
	(0.041)	(0.040)	(0.021)
Year 2007	-0.071*	0.083**	0.154***
	(0.043)	(0.042)	(0.022)
Year 2008	-0.115*	0.124**	0.238***
	(0.060)	(0.059)	(0.032)
Constant	-9.551***	3.556	13.110***
	(2.538)	(2.506)	(1.332)
Observations	950	950	950
Number of municipalities	95	95	95
Fraction of variance due to ind. Effects	0.946	0.633	0.983
Test for municipality effects	4.740	10.410	24.790
(pooled OLS vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]
Test for random effects	96.630	70.870	107.670
(random-effects vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]

*Note: Standard errors in round brackets; p-values in square brackets; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 3. Effects of Incentives Only for Towns in a Consortium

Dependent Variable (in logs) **Method: Panel OLS with Fixed Effects**	**Sorted Waste Ratio** **(1)**	**Per Capita Sorted Waste** **(2)**	**Per Capita Total Waste** **(3)**
PAYT	0.112***	0.089**	-0.023
	(0.036)	(0.035)	(0.018)
Additional years of PAYT	0.015	0.009	-0.006
	(0.010)	(0.010)	(0.005)
DtD	0.190***	0.083***	-0.107***
	(0.032)	(0.031)	(0.016)
Additional years of DtD	0.019*	-0.006	-0.026***
	(0.011)	(0.011)	(0.006)
No. of confining municipalities with PAYT	0.038***	0.046***	0.008*
	(0.009)	(0.009)	(0.004)
No. of confining municipalities with DtD	-0.010	-0.014	-0.004
	(0.009)	(0.009)	(0.005)
PAYT × No. of confining municipalities without DtD	0.029	0.013	-0.017*
	(0.019)	(0.019)	(0.010)
log(No. of inhabitants)	1.012***	0.193	-0.820***
	(0.303)	(0.298)	(0.156)
% Children aged 14 or younger	0.046**	0.037**	-0.009
	(0.018)	(0.018)	(0.009)
% Adults aged 65 or older	0.003	-0.005	-0.008
	(0.016)	(0.015)	(0.008)
% Non-native residents	-0.013*	-0.013*	-0.000
	(0.008)	(0.007)	(0.004)
% Unemployment rate in the district	-0.057	-0.012	0.045*
	(0.048)	(0.047)	(0.024)
Year 1999	-0.356***	-0.539***	-0.183***
	(0.066)	(0.0647)	(0.034)
Year 2000	-0.226***	-0.354***	-0.128***
	(0.063)	(0.062)	(0.033)
Year 2001	-0.201***	-0.275***	-0.074**
	(0.064)	(0.062)	(0.033)
Year 2002	-0.202***	-0.215***	-0.013
	(0.071)	(0.069)	(0.036)
Year 2005	-0.031	0.004	0.035**
	(0.032)	(0.031)	(0.016)
Year 2006	-0.078*	0.0491	0.127***
	(0.043)	(0.043)	(0.022)
Year 2007	-0.086*	0.066	0.151***
	(0.046)	(0.045)	(0.023)
Year 2008	-0.133**	0.105*	0.238***
	(0.064)	(0.063)	(0.033)
Constant	-10.000***	3.215	13.220***
	(2.756)	(2.708)	(1.415)
Observations	865	865	865
Number of municipalities	91	91	91
Fraction of variance due to ind. Effects	0.947	0.645	0.982
Test for municipality effects	4.340	9.300	22.800
(pooled OLS vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]
Test for random effects	93.810	72.040	110.430
(random-effects vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]

*Note: Standard errors in round brackets; p-values in square brackets; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Figure 1. Dynamics of policy management.

Municipalities implementing a given policy (%)

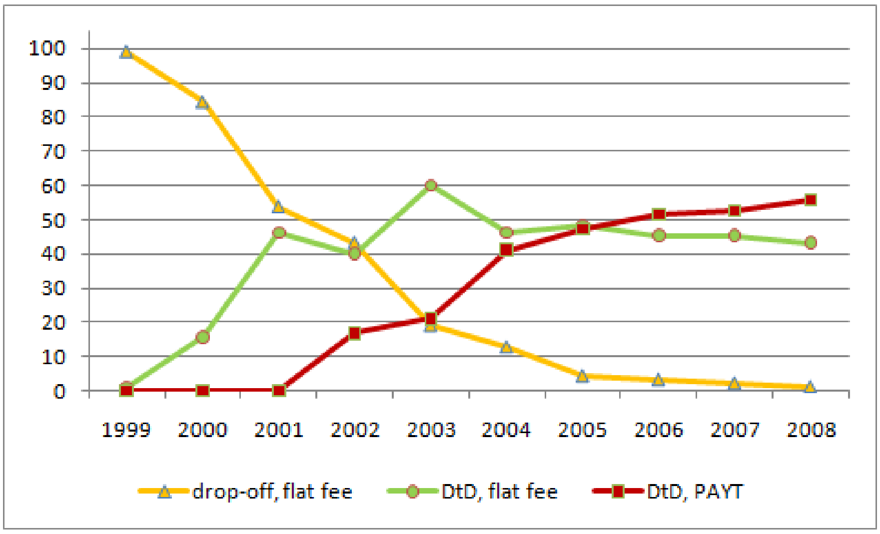


Figure 2. Dynamics of the sorted waste ratio.

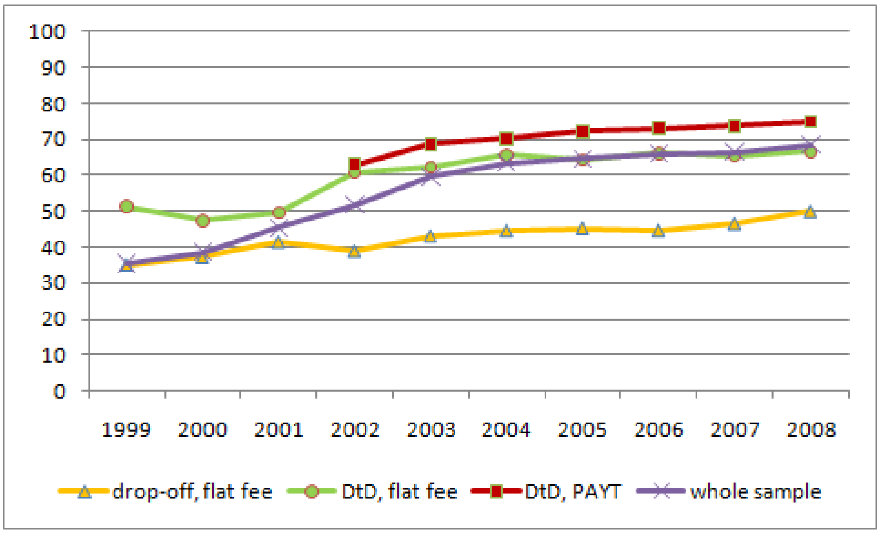


Figure 3. Average percentage growth in per capita total waste (base: 2002).