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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 waste management policies experienced during the years 1999–2008 by the 95 municipalities in the district of Treviso (Italy). We estimate with a panel analysis that pay-as-you-throw (PAYT) incentive schemes increase by 12.3% the sorted-total waste ratio. 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. Our data show that household behavior is also influenced by the policies of adjacent municipalities.

Keywords: Incentives, environment, waste management, PAYT.

JEL codes: D01, D78, Q53.

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1. Introduction

In this paper we study the effectiveness of monetary incentives in the context of domestic waste disposal. Nowadays this is considered a central issue in the policymaker's agenda, as the continuing growth in population size and wealth make our society produce increasingly more waste that we must eliminate somehow. 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, 2008; Health Protection Agency, 2005) with the consequence that citizens are even less willing to host such plants in their neighbourhood. A viable solution is then to ask domestic users to sort waste at home. However, sorting waste is not a pleasant activity: it requires considerable effort, a lot of time and attention. The goal of this paper is therefore to understand if monetary incentives can be used to increase the sorted waste ratio (the ratio between sorted and total waste), thus reducing the amount of unsorted waste that will end up in landfills and incinerators. As we explain below, the answer is not trivial and monetary incentives could even have a negative impact on the sorted waste ratio.

Historically, in Western countries households used to drop off all 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 been choosing to collect sorted waste door-to-door (DtD). DtD is a curbside collection system requiring users to separate their waste at home in a specific way (e.g. in bags, bins, etc) and following a specific calendar. DtD constitutes a nonmonetary incentive to sort waste, with a twofold effect: it makes sorting easier for the users, who do not need to carry their waste and drop it off along the streets, and at the same time it imposes limits on waste production, due to the constraint on the volume of storable waste and frequency of waste collection (Naslund, 1973). In addition to DtD, some local administrators abandoned the flat fee in favour of a per-unit fee, the so called "pay-as-you-throw" (PAYT) system. This pricing system aims to encourage waste sorting by linking the fee to the amount of residual (unsorted) waste actually produced. The PAYT pricing system generally requires a DtD collection to measure exactly the amount of unsorted waste produced (Kinnaman, 2006). Previous research shows that the *joint* adoption of DtD and PAYT produced outstanding results with an increase of the sorted waste ratio between 25% and 35% (see Miranda et al., 1994; Allers and Hoeben, 2010; and the literature review in Kinnaman, 2006).

However, not necessarily one should expect a positive effect on the sorted waste ratio of the PAYT incentive scheme, net of the effect brought by DtD. Compared to the municipalities that switched from drop-off to DtD collection throughout the world, only few adopted PAYT as opposed to flat fee. One of the reasons is that PAYT may induce users to "hide" part of their waste to pay a lower fee (see, e.g., Fullerton and Kinnaman, 1996: Levitt and Dubner, 2009); another is that policy makers may be reluctant toward PAYT since they fear that an increase in user fees can disappoint the voters (De Jaeger, 2011). In addition, from a psychological point of view, introducing a pricing system that sets a price for the production of unsorted waste, may crowd out the users' intrinsic motivation to sort (see, e.g., Ariely et al., 2009; Benabou and Tirole, 2003; Gneezy and Rustichini, 2000; Fehr and Falk, 2002). Our aim is to provide a proper assessment of the net effect of PAYT, using reliable administrative data.

In this paper we use a unique panel dataset to disentangle the effect of PAYT from the effect of DtD on the amount of waste sorted by domestic users. In addition we study the effects of PAYT over time and over space. In particular, over time we isolate the potential "learning" effect of every additional year of DtD and PAYT, because users may need time to fully understand the incentive and adjust their behavior accordingly (see, e.g., Missios and Ferrara, 2011). Over space, we investigate the relevance of the perverse behavior of hiding waste and dump it illegally in adjacent municipalities to pay lower fees.

To this end, we collected annual administrative data on waste disposal over the years 1999–2008 for the 95 municipalities in the district of Treviso, Italy. We then merged this dataset with data on the demographic characteristics of each municipality, provided by the Italian National Institute of Statistics. The resulting dataset allows us to control for many relevant characteristics of these municipalities and their inhabitants, and to estimate the effect of these variables on the sorted waste ratio.

Our final dataset is unique for at least three reasons. First, prior to the period we consider, a law divided the district in three geographic zones, each managed by a different consortium to which most municipalities adhered. This means that nearly all the municipalities in our sample were not directly responsible for the decisions on waste management; they just followed the policy of their consortium. We argue that this exogenous intervention removes the potential endogeneity problem that is otherwise present in similar studies (an exception is represented by Kinnaman and Fullerton, 2000), where different municipalities may choose different waste management policies; however, in our analysis we investigate whether the decision of the waste management policy is indeed exogenous. Second, our sample includes wide heterogeneity of policies on waste collection (drop-off, DtD) and payment method (flat fee, PAYT) enabling us to estimate separately the effect of these policies. 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.

Our results show that well-designed monetary incentives are effective even in the context of domestic waste disposal. We find that the introduction of a PAYT system has a significant and positive net effect of 12.3% on the sorted waste ratio, which is complementary to the positive effect induced by DtD, 15.2%. In addition, the ratio increases by an additional 9.2% when adjacent municipalities implement PAYT, and it falls by 11.1% when adjacent municipalities implement neither PAYT nor DtD. Moreover, we find some evidence suggesting that illegal dumping may be a relevant issue at the aggregate level, at least in municipalities starting from low sorted waste ratios. 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 Section 4 reports the results. Section 5 discusses some open questions and presents the directions of our future research. Two final appendices provide further details on the data and the waste management systems in these municipalities.

2. The Data

We collected administrative data on the amount of waste produced annually between 1999 and 2008 in the municipalities of the district of Treviso, in north-eastern Italy; further details on this small but highly populated district are given in Appendix A.1. Overall we have 10 annual time series observations for each of the 95 municipalities in the district. We ignore data before 1999 because they may be affected by measurement error, as municipalities were still in the process of organizing their waste management. 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 sorted waste and total waste)[1] 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%). Many of these municipalities are now among the best practitioners of waste management in Italy (Legambiente, 2009) as well as Europe, exceeding by far the targets of sorting set by the European Commission (Eurostat, 2010). However, the sorted waste ratio in the district was not outstanding in the late '90s when DtD and PAYT have been introduced. In the same years, other regions in Northern Italy were sorting more than the district of Treviso (ISPRA, 2011) and countries such as Germany and the Netherlands were achieving sorting ratios around 30-35% (Eurostat 2003). Hence, the excellent results the municipalities obtained in more recent years are possibly related to the change in waste management policies arisen over the decade we consider in the analysis.

The building blocks of our dataset are two: first, annual data on sorted and unsorted waste production at the municipal level provided by the Regional Agency for Environmental Prevention and Protection of Veneto (*Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto*, Arpav), that we double-checked with the data available to the consortia; second, raw data on the demographic characteristics of each municipality, provided by the Italian National Institute of Statistics (*Istituto Nazionale di Statistica*, Istat), and further elaborated by the statistical unit of the Veneto region.

Importantly, in our dataset we observe different policies along two dimensions: the collection system (drop-off as opposed to DtD) and the pricing system (flat fee as opposed to PAYT). Appendix B provides details on the collection and pricing systems. Here we briefly describe the two pricing systems. The *flat fee* is proportional to the user's house surface and /or the number of household members:

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

where ϕ_0 and ϕ_1 are the costs, respectively, per square meter and per household member. In this system there is no direct link between the actual production of waste and the fee paid,

[1] Because sorted waste is potentially recyclable, many authors use the term "recycling ratio" instead of sorted waste ratio (Kinnaman, 2006).

even though the number of house 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 *pay-as-you-throw fee* establishes a direct link between costs and user's sorting behavior. It is made of a fixed part – which can be identical for all users or determined according to specific parameter, as the number of house square meters, etc. – and a variable part depending on the amount of the unsorted waste produced:

$$PAYT = \theta_0 + \theta_1 \times \left(No.\ of\ emptyings\ of\ unsorted\ waste\ bin \right) \quad (2)$$

where θ_0 and θ_1 are, respectively, the fixed cost and the cost per unsorted waste bin emptied. Notice that the above formula measures the production of unsorted waste in terms of frequency (number of emptyings) rather than mass (kilograms of waste), which happens to be less expensive to implement (Allers and Hoeben, 2010)[2]: to matter for the calculation of the fee is only the number of emptyings of the bin for unsorted waste, disregarding whether the bin is filled or not. [3]

According to equation (2), accumulating unsorted waste is relatively costlier than accumulating sorted waste. This may induce users to sort waste inappropriately in order to lower the amount of unsorted waste. For this reason a system of monitoring and sanctioning is applied jointly with the municipal authorities. Monitoring is simplified by the requirement to use transparent bags to store unsorted waste in the bins, and no bag to store sorted waste. This makes it easy to check if a household is indeed sorting waste properly; see Appendix B.3 for further details.

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. Since 2000, municipalities gradually started changing the policy; as of 2008, 41 out of 95 were implementing DtD with flat fee pricing, 53 were implementing DtD with PAYT pricing,

[2] In fact, PAYT pricing may be linked to either the mass or the frequency of waste. This latter method of counting unsorted waste may give rise to the infamous "Seattle Stomp", where residents compact waste into the bin to reduce the number of emptyings. Although less expensive to implement and manage, volume-based fees seem less effective than mass-based fees in reducing the production of unsorted waste (Allers and Hoeben, 2010). In our analysis, however, we assess the effectiveness of the frequency-based fee using a mass measure.

[3] Bins for unsorted waste have a capacity of 120 liters and they may be emptied every two weeks, for a total of 26 times per year. However, bins are emptied much less frequently (usually between 5 and 8 times per year in our sample, depending on the household size) because they are charged a cost. After each differentiable fraction of waste is sorted, the quantity of non-sortable waste is conspicuously reduced and it produces no smell. Therefore it can be easily stored for several weeks until the bin is filled.

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 (306 observations), DtD with flat fee (372 observations), and DtD with PAYT (272 observations). We observe no municipalities implementing drop-off and PAYT. In fact, systems with drop-off and PAYT are rarely seen (Reschovsky and Stone, 1994; Kinnaman, 2006), because they make 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 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. Our analysis in Section 4 investigates whether the higher sorted waste ratio we observe in this case is indeed attributable to the different waste management policy.

FIGURE 2 ABOUT HERE

2.1. Exogeneity of the Policy Assignment

In the late 1980s a regional (frame) law identified three geographic areas within the district and encouraged the creation of independent, non-profit consortia of municipalities within each area. The regional authority asked – but did not force – each municipality to join the consortium in its area. After joining a consortium, a municipality delegates all decisions to the consortium; therefore, the municipality is no longer able to make independent decisions on waste management but it had to follow the prescriptions of its consortium, made by a board of managers.

The district of Treviso was the first to follow the regional directions. At the end of 2008, 91 municipalities out of 95 joined the consortium operating in their area; these municipalities joined their consortium in different years since they had to wait the expiration of previous waste management contracts.[4] Four municipalities remained independent, essentially for

[4] Before the law was introduced, municipalities were in charge of the management of solid waste disposal, and they used to contract the provision of this service through external companies. In many cases, before joining a

structural or geographic reasons; further details on the history of these municipalities and consortia are given in Appendix A.2. Our main analysis, shown in Sections 4.1-4.3, is based on 10 annual observations for all the 95 municipalities. In a robustness check, reported in Section 4.4, we repeat the analysis based on a smaller sample, including only the municipalities belonging to a consortium, and only in the years following adhesion.

As mentioned earlier, in our dataset we observe 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 effect of the introduction of PAYT net of the effect of adopting a DtD collection. This environment resembles a quasi-natural experiment, because the collection and pricing systems are imposed to the municipality by the consortium and, hence, they are not chosen directly by the municipality (see Appendix A.2 for more details).[5]

One might argue that the selection of the policy is not a completely exogenous mechanism, as municipalities can influence somehow the decisions of their consortium board and the director. In particular, municipalities with more concern about sorting might push for the implementation of DtD and PAYT policies. If that were the case we should see that, before the implementation of new policies, such municipalities were having higher ratios of sorted to total waste, and /or they were increasing this ratio faster than the other municipalities.

To investigate this issue we focus on the 91 municipalities belonging to a consortium in 2008, we split them in several groups according to the policy they eventually chose, and we test whether these groups had different characteristics in 1997, that is, two years before the initial period in our sample (1999). Specifically, we compare two groups in terms of the sorted waste ratio they had in 1997, or the variation in their ratio between 1997 and 1999. As mentioned above, data before 1999 are not completely reliable for some municipalities. For this reason we compare different groups by means of a Pearson's non-parametric median test, which is more robust to errors than alternative tests based on the mean or the data distribution.

We distinguish the sample of municipalities according to the policies they followed in 2008, where 39 municipalities were implementing DtD collection with flat fee pricing, and 52 were implementing DtD collection with PAYT pricing. Hence we test whether municipalities

consortium they had to wait until the expiration of previous waste management contracts. For instance see http://www.comune.morgano.tv.it/ecologia.asp for the municipality of Morgano.

[5] Ordinary decisions in each consortium are taken by a director and a board of managers, who is elected following a majority principle by the majors of all the municipalities adhering to the consortium; the representativeness of each municipality depends on the percentage of its population. Decisions on the waste management policy, however, have been made just once, right after the creation of the consortium, by the director, the managers and the majors involved at that time.

choosing PAYT are systematically different than others. The chi-squared statistic of the Pearson test is worth 2.477 (p-value: 0.116) as regards the sorted waste ratio in 1997, and 3.297 (p-value: 0.069) as regards the percentage variation in the ratio between 1997 and 1999. Therefore, we do not find strong evidence of a systematically different pattern between those implementing PAYT and those not implementing it.

Similarly, if we divide the sample according to the policies adopted in 2001, where 48 municipalities were implementing drop-off collection with flat fee pricing, and 43 DtD collection with flat fee pricing, we find a statistic of 0.012 (p-value: 0.912) regarding the sorted waste ratio in 1997, and 0.096 (p-value: 0.757) regarding the percentage variation in the ratio between 1997 and 1999. Also in this case, the data suggest that municipalities adopting DtD are not systematically different from municipalities not adopting it.

Although not conclusive, this evidence overall supports the view that there are no intrinsic differences between the municipalities adopting one policy instead of another, and thus the assignment of a specific policy is exogenous.

3. Empirical Strategy

Our empirical strategy is designed to verify the net effect of introducing 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 a nonmonetary incentive (DtD).

The main analysis is based on the following model, where i denotes the municipality and t denotes 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. Our benchmark for the dependent variable Y_{it} is the logarithm of the percentage sorted waste ratio (the ratio between the amount of sorted and total waste); in addition we consider the logarithm of per capita (sorted, unsorted, total) waste in kilograms.[6] A consequence of taking logarithms in the left-hand side of equation (3) is that

[6] Notice that, although the PAYT formula refers to the frequency of unsorted waste disposal, we assess its effectiveness in terms of mass (kilograms).

the coefficients can be interpreted as relative variations in the dependent variables (thus, abstracting from their scale) in response to unitary variations of the explanatory variables.

Estimation is performed by means of a fixed-effects panel regression model with standard errors clustered at the municipality level. 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 the (fixed) heterogeneity among 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 2-4.

Below we describe the explanatory variables in equation (3) that we group in four sets $\left(P_{it}, C_{it}, D_{it}, T_{it}\right)$, 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 define the dummy variable "DtD" equal to 1 when the municipality is implementing DtD and the dummy variable "PAYT" equal to 1 when the municipality is implementing PAYT. The latter variable captures the effect of PAYT net of DtD because, whenever a PAYT policy is implemented, a DtD policy is always also 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 interpret it as an indication 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 assume that this learning process follows a linear trend,[7] and we

[7] PAYT and DtD programs in our sample started just a few years ago, and we do not have enough observations to treat further degree polynomials.

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.

Context Variables

Set C_{it} includes three variables capturing the context faced by the municipalities. As we know, each municipality may adopt one of three policy combinations: DtD collection with PAYT billing, DtD collection with flat fee billing, or drop-off collection with flat fee billing. The first option provides both monetary and non-monetary incentives to sort waste, while the third option gives no incentive at all to sort waste. We expect that proximity to municipalities with or without incentives may influence the decision to sort waste.

We therefore consider a dummy variable equal to 1 if the municipality has at least one adjacent municipality adopting DtD and PAYT, and another dummy variable equal to 1 if the municipality has at least one adjacent municipality adopting drop-off and flat fee. In the first case we expect a positive "emulation effect" on the sorted waste ratio, with citizens sorting waste to a larger extent just because their peers in near municipalities are forced to do so. In the second case we expect a negative "dismay effect", with citizens losing interest in sorting waste because their peers in near municipalities do not pay much attention to the issue.

Finally, we consider a third dummy variable that is equal to 1 if the municipality implements PAYT, *and* at least one adjacent municipality adopts drop-off and flat fee. In our intention, this variable should capture a potentially positive "hiding effect" on the sorted waste ratio.[8] In fact, illegal dumping is one of the main concerns for introducing PAYT: Fullerton and Kinnaman (1996) estimate that 28% of the observed reduction of waste might be due to improper or illegal disposal. In principle, users might throw unsorted waste in the bins for sorted waste; however, as mentioned in Section 2, garbage collectors would easily discover and sanction it. Alternatively, users might dump their waste in any place, for instance in their neighbours' property or in the street. It should be noticed, though, that in the district under investigation i) each user is responsible for its bin, which is usually kept indoor, and ii) in the streets there are no common bins where to throw waste, since the municipality adopts a DtD collection method. If users really wanted to hide their waste the only viable

[8] In principle this effect should also be observable, in the opposite direction, if we considered a dummy variable equal to one for a municipality implementing a drop-off system with flat fee, with at least one adjacent municipality adopting PAYT. In practice, this variable is generally equal to 0, especially in the latest years of our sample; this creates quasi-collinearity problems and makes it difficult to find a significant hiding effect.

options are: burn it, throw it in the countryside or in a forest area, or throw it in a nearby municipality implementing drop-off, where common bins are available in the streets. The latest is a pretty easy option in this district, where municipalities are very close to each other, and many individuals regularly commute for work. Citizens are well aware of this option even as a consequence of the many articles reported in local newspapers.[9] Since the cost of moving from one municipality to the other is minimal, users living in municipalities following a PAYT program may choose to throw away their unsorted waste in nearby municipalities that are still under a program with drop-off collection, so that they can pay lower fees (the "hiding" effect). To limit this "garbage tourism", municipalities with drop-off waste collection put the most sensible bins under CCTV surveillance and ask their citizens to report observed misbehaviour in waste disposal to environmental guardians or local authorities (see Appendix B.3 for more details).

Demographic Variables

Set D_{it} takes into account variations in the demographic composition of the municipality: the logarithm of the population density (inhabitants per square kilometre), the percentage in the population of children aged 14 or younger, the percentage in the population of individuals aged 65 or older, and the percentage in the population of non-native residents. All these variables show a pattern linearly increasing over time, with the population density going from an average 295 inhabitants per square kilometre in 1999 to an average 339 inhabitants per square kilometre in 2008, the percentage of children going from 14.41 to 18.16 percent, the percentage or retirees from 16.93 to 17.86 percent, the percentage of non-native residents from 3.48 to 11.24 percent.

We include these variables for three reasons: first, the population density gives a measure of the complexity of waste collection. We expect municipalities with higher density to be structurally different than smaller municipalities with lower density, 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.).

[9] See for example the collection of articles published in 2007 and 2008 on local newspapers available online in the website of "Treviso Servizi", the company managing the waste collection in the municipality of Treviso: http://www.trevisoservizi.com/index.php?title=rassegna.

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 (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 period 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

Section 4.1 discusses the effects on the sorted waste ratio, while Section 4.2 focuses on the effects conditional on the initial level of the sorted waste ratio. Section 4.3 comments on the effects on the mass of sorted, unsorted and total waste. Finally, Section 4.4 discusses a robustness check with a subsample of observations.

4.1. Effects on the Sorted Waste Ratio

Our main results are shown in Table 2. Among the explanatory variables of equation (3) and discussed in Section 3, the regression in Column 1 includes only the dummy variable on PAYT, and the demographic and time variables; the regression in Column 2 also considers the dummy variable on DtD; finally, the regression in Column 3 includes all the policy, context, demographic and time variables described in Section 3.

TABLE 2 ABOUT HERE

Following the literature, the specification in Column 1 measures the effect of the PAYT policy alone, without trying to disentangle it from the effect of DtD collection. We find a significantly positive and large effect of the policy, informing that the introduction of PAYT raises the sorted waste ratio by a large amount (28.9%.) This number is in line with previous estimates in the literature (see the results reported in Kinnaman, 2006), derived from different datasets that do not distinguish between the effects of DtD and PAYT.

The specification in Column 2 makes a split between the effects of PAYT and DtD. Although significantly positive, the effect of PAYT (24.3%) is now slightly lower than in Column 1. The reason is that we also find a significantly positive effect of DtD (16.3%), consistently with previous works on the comparison between drop-off and DtD collection methods (see, e.g., the literature review in Kinnaman, 2006). When not controlling for the collection method, therefore, the effectiveness of the PAYT is over estimated. Our finding that both the PAYT and the DtD have a positive and significant effect on the sorted waste ratio supports the hypothesis that the monetary incentive of PAYT is *complementary* to the nonmonetary incentive of DtD. The absence of negative (crowding-out) effects may suggest that the incentive is well designed and aligned to the users' intrinsic motivations.

Column 3 of Table 2, which adds all the variables to the specification, also supports a significantly positive effect for both PAYT (12.3%) and DtD (15.2%). The smaller size of the coefficient on PAYT compared to Column 2 may suggest that in the previous regression the coefficient was incorporating also the effect of omitted variables. Indeed, in Column 3 we also find evidence of an "emulation effect": the sorted waste ratio rises by 9.2%, even in the absence of incentives in the waste management system, just because adjacent municipalities implement PAYT. In our view, users observe the behavior of their peers in adjacent municipalities and tend to replicate it in their municipality.

Interestingly, there is evidence of a "learning effect" of PAYT (the sorted waste ratio increases by an additional 3.1% for every further year of PAYT) but not of the DtD collection methodology. We also find evidence that the presence of adjacent municipalities adopting a drop-off collection system has a negative effect (-11.1%) on the sorted waste ratio. We interpret this as a "dismay effect": the proximity to environments in which citizens are not required to make any particular effort in sorting (resulting in a low sorted waste ratio) may weaken the motivation to sort, diminishing the effect of the monetary incentive. The size of this effect is so high that it can potentially offset the positive effect of PAYT.[10] Moreover, we also find weak evidence (significantly at 10%) of a "hiding effect" of throwing waste

[10] The sum of the two coefficients, 0.123-0.111, is not significantly different from zero at the 5% level: F test 0.03, p-value 0.856.

produced in municipalities with PAYT in adjacent municipalities with drop-off collection. In this case, the sorted waste ratio in the municipality with the PAT increases by 12.7%.[11] Despite the possibility to make illegal disposal is relatively simple (due to the closeness of municipalities and the high number of persons commuting for work), our results do not suggest that this option is clearly exploited (the coefficient is only significant at 10% level). We believe this may happen because of a social image concern: citizens fear to be caught in illegally disposing the waste, therefore signalling misbehaviour or their poorness (considering that the cost for the emptying of the unsorted waste bin is not high).

All our findings are net of the effects on demographic and time variables. However, only including the coefficients of the year dummy variables seems relevant, and it suggests – not surprisingly – that the sorted waste ratio tends to increase anyway over the years, plausibly as a consequence of a massive media campaign in the latest years.

One concern with the implementation of PAYT is that it carries higher management costs, which are (at least partly) paid by the users. As a final remark, we want to point out that with PAYT we find an increase in the sorted waste ratio, and this increase has virtually no cost to the households. In 2008 the per-capita cost was 96.00 Euros in consortium TV3 (DtD collection and flat fee) and 95.50 in consortium Priula (DtD and PAYT).[12] This happens because in the municipalities where PAYT is active, households have a strong incentive to reduce the production of unsorted waste.

4.2. Effects Conditional on the Initial Level of the Sorted Waste Ratio

Our analysis so far shows that both DtD and PAYT programs considerably increase sorting. However, the effectiveness of monetary and nonmonetary incentives may depend on the initial level of the sorted waste ratio, and one may expect the effect to be lower in municipalities already having a high sorted waste ratio. In this Section we focus our attention on this issue; our outcome results are shown in Table 3. First, we repeat the regressions in Column (3) of Table 2 separately in two sub-samples of municipalities: weak and strong sorters. We define “weak sorters” the municipalities with a sorted waste ratio below the first quartile in 1999 (37.68%), and “strong sorters” the municipalities with a sorted waste ratio above the third quartile in 1999 (44.25%).

[11] In a separate regression, not reported, we included the interaction between the hiding effect and the additional years of PAYT, to understand whether hiding emerges gradually over time. Our results do not support this statement, and we find that hiding is stable over time.

[12] From the Arpav website, http://www.arpa.veneto.it/rifiuti/htm/banca_dati_ru.asp.

TABLE 2 ABOUT HERE

The output of this analysis is shown in Columns 1 and 2 of Table 3. We find some interesting results. In particular, we find context to be relevant only for weak sorters: indeed, only here there is evidence of an emulation effect (20.6%), a dismay effect (-21.7%) and a hiding effect (23.2%). More importantly, the net effect of PAYT is significantly different from zero in both groups, but it is larger among weak sorters (18%, as opposed to 11.7% for strong sorters). This, together with the positive learning effect of PAYT (3.5%) we observe only among weak sorters, possibly indicates that among weak sorters there are higher margins to increase the ratio further. In contrast, the effect of DtD is significantly positive only among strong sorters with a size of 16%.

Figure 3 summarizes the average marginal effect of both policies, separately by the initial level of the sorted waste ratio. Effects and confidence intervals are derived from a Blundell-Bover panel regression with the same specification as in Column (3), but including the (log) sorted waste ratio in the previous year, and its interaction with the dummy variables for PAYT and DtD; the output from this regression is shown in Column (3) of Table 3. The figure shows a clear pattern, with PAYT becoming progressively *less* effective as the municipality starts from a higher sorted waste ratio, and DtD becoming progressively *more* effective as the municipality starts from a higher sorted waste ratio; the link with the initial sorted waste ratio is however higher for PAYT. The figure informs that, for instance, if a municipality starts from a sorted waste ratio of 20%, implementing DtD has no significant net effect, while implementing PAYT has a net effect of increasing the ratio by 70% (from 20 to 34%); in contrast, if a municipality starts from a sorted waste ratio of 60%, implementing DtD has a net effect of increasing the ratio by 30% (from 60 to 78%), while implementing PAYT has no significant net effect. In general, the confidence intervals in Figure 3 (the shaded areas) suggest that DtD has a significantly positive effect if the initial sorted waste ratio is not lower than 25%, whereas PAYT has a significantly positive effect if the ratio is below 60%. It thus seems that the monetary incentive of PAYT prevails over the non-monetary incentive of DtD only when the municipality has a low production of sorted waste.

FIGURE 3 ABOUT HERE

4.3. Components of the Sorted Waste Ratio

We then look more closely at the components of the sorted waste ratio: sorted waste, unsorted waste and total (sorted plus unsorted) waste. Table 4 shows the estimates of the model in equation (3), where the dependent variable is now the logarithm of per capita sorted waste (Column 1), per capita unsorted waste (Column 2) and per capita total waste (Column 3) in kilograms. In Columns 4 and 5 we repeat the estimation on the per capita total waste for the weak and the strong sorters.

TABLE 4 ABOUT HERE

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 analyses in Table 2, 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 unsorted waste, PAYT makes it more convenient to increase sorted waste. In contrast, if the incentive is well designed and effective, the introduction of PAYT should have no bearings on the production of total waste, producing just a shift from unsorted to sorted waste. Clearly, when making more expensive the production of unsorted waste, an alternative for citizens might be to buy products with less packaging. This would actually lead to a reduction in the amount of total waste. However, at least in the Italian context, this is not a real option since consumers do not have the possibility to choose among products with different levels of packaging. They rather face a uniform reduction in the packaging which is promoted at the national level by the national packaging consortium (*Consorzio Nazionale Imballaggi*, CONAI), a specific agency that essentially encourages firms to reduce the packaging of their products.[13]

The regression output supports our hypothesis. Indeed, we find for PAYT a significantly positive effect on per capita sorted waste (which rises by 12.4%; see Column 1) and a significantly negative effect on per capita unsorted waste (which decreases by 20.3%; see Column 2), while an insignificant effect on per capita total waste (the coefficient 0.001 is statistically equal to zero; see Column 3). This also suggests that users do not hide waste in the presence of this payment system, unless they have a nearby municipality with street bins

[13] Moreover, the shift toward products with less packaging encouraged by policymakers (see for example the Directive 2004/12/EC of the European Parliament) is not automatic especially in consideration of the new lifestyle (i.e. increase of single person households, tendency to consume meals outside) offsetting the technological improvements in packaging waste prevention, (EEA, (2005). For further information about the Italian case see EEA, (2005) and also www.conai.it.

for drop-off collection. In fact, in Column 3 we find a significant hiding effect (-7.2%) for total waste, that seems to regard only weak sorters (-10.4%, Column 4). In addition, we find that the dismay effect concerns all the waste components, and it is relevant especially for weak sorters (Column 4), while the emulation effect of nearby municipalities with PAYT is significant only for sorted waste (9.9% for each nearby municipality, see Column 1). We interpret this result as evidence that citizens are likely to follow the sorting behavior of the neighbourhoods. This observation may influence their sorting behavior more than the total production of waste, which is rather linked to consumption habits. In this case, in line with Cailas *et al*. (1993) and Jenkins (1993), we also find that higher population density reduces the overall production of waste, possibly because municipalities with higher population density on average have houses with smaller surface, which in turn may induce more attention in buying products with less packaging.

The effectiveness of PAYT is confirmed by the evidence of a learning effect that is significantly positive for per capita sorted waste (which increases of about 2.4% for every further year of PAYT adoption) and significantly negative for the unsorted waste (which decrease of 4.2% for every subsequent year of PAYT adoption). These results confirm that PAYT does not affect per capita total waste production, but it rather induces users to shift from unsortable to sortable products.

In contrast, we find that DtD reduces per capita unsorted waste (by 3.22%; see Column 2) and it also reduces per capita total waste (by 10.1%; see Column 3). Surprisingly, it does not significantly increase the production of sorted waste (the coefficient 0.050 in Column 1 is not significant). We also find a learning effect of DtD on total waste (that is reduced by 2.5% every further year). This effect supports the view that DtD is a form of nonmonetary incentive aimed at 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), while eliminating the time costs of carrying waste to the streets. While DtD induces a reduction in the production of total waste it does not seem effective in increasing sorted waste. Hence, even if we observe a similar effect in the sorted waste ratio, the PAYT fee reaches this goal by sorting more waste, while the DtD collection method reaches it by producing less waste.

Our results suggest that monetary incentives are an effective tool in fostering the sorting behavior at the municipal level, and potentially they can be adapted to reach further goals, primarily the reduction of per capita total waste (European Union, 2008). In fact, in Column 3 of Table 4 we find that the production of total waste tends to increase over time.[14] 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.

4.4. Robustness Check

We conclude the analysis 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 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 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 Appendix A.2). 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 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 5. Our previous results are largely confirmed, both qualitatively and quantitatively. In particular, we find for PAYT an effect on the amount of sorted waste of 11.7% (from Column 1, as opposed to 12.4%), and no effect on the amount of total waste (from Column 2, as in the benchmark), and an effect on the sorted waste ratio of 11% (from Column 3, instead of 12.3% as in the benchmark). If we then split the sample in the two groups of weak and strong sorters (Columns 4 and 5), our previous findings are also essentially confirmed. In particular, among strong sorters we still find a smaller effect of PAYT (12.4%) and a larger effect of DtD (15.3%), while only among weak

[14] Environmental economists link the growth in the production of waste, as well as the growth in the production of energy, to the increase in wealth and welfare (measured by the GDP). In the future they expect this high correlation to reduce, because of a more widespread concern for the environment. However, while there is already evidence of a "decoupling effect" on the production of energy, the production of waste still seems to follow closely the growth of GDP (Mazzanti and Zoboli, 2008).

sorters we still find evidence of emulation, dismay and hiding effects (respectively 18.5%, -24.9% and 24.5%).

TABLE 5 ABOUT HERE

5. Conclusions

In this paper we study the effectiveness of the monetary incentive represented by PAYT on the ratio of sorted to total domestic waste. Our results suggest that, when well designed, monetary incentives work. Indeed, we find that the PAYT incentive increases the sorted waste ratio by around 12.3% and that it is complementary to the effect of the DtD incentive (15.2%). In addition, municipalities with a PAYT program increase the amount of per capita sorted waste by 12.4%, 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 tool; hence policy makers should not … trash monetary incentives, but rather use them to increase the sorted waste ratio. However, we find that a PAYT policy also induces an undesired hiding effect: users throw their waste in adjacent towns where common bins are available in the streets – at least in municipalities where the sorted waste ratio is relatively low. Therefore, a coordination of policies at a macro level is necessary to avoid this undesired effect.

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. In our future research we will focus on the following three 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. 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. 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. We tend to exclude that this issue has a major effect on the aggregate results of the current paper, since on average in our dataset there are 1.48 households for every building. This suggests that apartment buildings are not so frequent in the district of Treviso.

Appendix A. Municipalities and Consortia in the Dataset

In this appendix we describe the municipalities in the district of Treviso (Section A.1), the changes introduced by the 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 coloured area) is located in north-eastern Italy, in the region called Veneto (the lighter coloured area).

FIGURE A.1 ABOUT HERE

The district covers an area of 2,477 square kilometres. It is one of the most highly populated Italian districts (879,408 inhabitants in 2008), with a relatively high population density (355 inhabitants per square kilometre) and a relatively high rate of population growth (the birth rate is 1.07% and the percentage of legal immigrants is 10.9%[15]). The district is divided into 95 municipalities, all close with each other and almost all of relatively small size; an average municipality has 9,303 inhabitants. Only one municipality, Treviso, has 82,206 inhabitants; 24 municipalities have between 10,000 and 50,000 inhabitants; 36 between 5,000 and 10,000, and 34 fewer than 5,000 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 for "optimal territorial scope" (*Ambito Territoriale Ottimale,* ATO). The office sets targets on landfills for biodegradable municipal waste and separate collection of municipal waste. Districts are responsible for

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

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 at any time the "consortium" managing their territorial unit (see Figure A.2). Once a municipality joins a consortium, it can no longer exit and it delegates all decisions regarding waste management to the consortium board.

FIGURE A.2 ABOUT HERE

Participation was gradual since, according to the regional plan, municipalities were allowed to join the consortium in later years, in order to let expire any active waste management contract previously signed. 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 four exceptions are Colle Umberto, Tarzo, Mogliano Veneto, and Treviso, which chose not to adhere, respectively, to Savno (the first two municipalities), Priula, and TV3.[16]

FIGURE A.3 ABOUT HERE

A.3. The Three Consortia

We now report some facts on the three consortia.

Consortium Priula (www.consorziopriula.it), created in 1987 with the adhesion of 5 municipalities, now includes 24 municipalities covering an area of 640 square kilometres with around 240,000 inhabitants. In 2000 the consortium, constituted by 14 municipalities, decides

[16] Geographical limits for Colle Umberto and Tarzo, and high population density for Treviso, prevent these municipalities from freely choosing a waste management system. In contrast, Mogliano Veneto chose to follow a waste management system in line with the adjacent municipalities in the district of Venice.

to introduce the DtD and the PAYT system. In 2008 the municipalities in the consortium reached a sorted waste ratio of 77.06%, gaining first place in national rankings (Legambiente, 2009).

Consortium TV3 (www.tvtre.it), created in 1993 with the adhesion of 25 municipalities, and operates within a territory of 620 square kilometres having around 220,000 inhabitants. In 2000 the consortium decides to introduce the DtD system. In 2008 the municipalities in the consortium reached a sorted waste ratio of 66.56%.

Consortium Savno (www.savnoservizi.it), created in 1995 with the adhesion of 6 municipalities, now 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 all the municipalities were adopting the same collection methods (drop-off) and pricing systems (flat fee), since 2000 they 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 unsorted nonrecyclable waste produced. The volume is measured by counting the number of times during the year that specific trash bins of unsorted waste are emptied. These bins have a capacity of 120 litres and are emptied no more often than every two 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 annual cost per household was approximately 140.11 euros in Priula.[17]

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 semester 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 affected by the transition from one system to the other (our end-of-year data would be a mix between what happened in both the first semester with flat-fee pricing,

[17] 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.

and the second semester with PAYT). In 2008 the annual cost per household was approximately 140.84 euros in TV3.[18]

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.

In each municipality where a DtD program is active, the recyclable fractions of waste (e.g. organic, plastic, paper, glass, cans, etc) are sorted by each user in the house and then stored into specific bins provided by the consortium which have identical capacity for each user. The collection of each fraction has different frequencies and follows a calendar. Specific instructions are given for sorting every fraction of recyclable waste: i.e., glass and plastic containers have to be cleaned and every piece of paper on them has to be removed, otherwise the workers in charge cannot collect them.

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). We conclude this appendix with details on the monitoring and sanctioning activity.

B.1. Waste Collection Systems

In 1999 all 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 ABOUT HERE

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

[18] 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).

on which it is going to be collected, where bins are placed in the streets, just outside each house.

FIGURE B.2 ABOUT HERE

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 ABOUT HERE

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 ABOUT HERE

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 unsorted 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 unsorted 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 ABOUT HERE

The calculation of the PAYT fee is made according to Eq. (2) and it is proportional to the number of emptyings of an unsorted waste cart. Fixed and variable costs vary over the years; in 2008 the average fixed cost was equal to $\theta_0 = 82.38$ Euros, and the average variable cost was equal to $\theta_1 = 10.39$ euros per emptied waste bin. 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 ABOUT HERE

B.3. The Monitoring Activity and Sanctioning System

In order for the PAYT system to be effective, it is necessary to detect and sanction irregularities in the waste sorting with monitoring activities.

The monitoring activity is assigned to both the waste collectors and to the so-called "ecovigili" (environmental guardians) with the power to inspect the quality of sorting also in the users' house by their own initiative or by call of other citizens. The management staff of consortium Priula told us that around 2,000 inspections are run every year in the district of Treviso. Once an irregularity is detected, by either the waste collector (see the report sheet in

Figure B.6) or the “ecovigili”, each consortium applies sanctions which usually consist of monetary fines but can even start a judicial procedure in front of a court.[19]

FIGURE B.6 ABOUT HERE

Generally monitoring and sanctioning systems are implemented not only in the municipalities where a flat fee is applied but they are sometimes operating in municipalities where waste is collected with a drop-off method. In this second case, as in Treviso, for example, the monitoring system is also conducted by the company in charge of the waste management who associate to each neighbourhood of the city an environmental operator who has the task of taking care of the correct waste collection and sorting in that area and of detecting irregularities in sorting preventing illegal dumping by inhabitants of adjacent municipalities where a PAYT system is adopted. In addition, in the city of Treviso many bins are under CCTV surveillance, especially those in areas where garbage tourism is more likely.

[19] For example, for the consortium Priula, rules for inspections and fines are reported in the document (in Italian) available at (www.consorziopriula.it/dynamic_downloads/_133_Regolamento_gestione_2006.pdf.

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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
Unsorted 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
If adjacent municipalities with DtD and PAYT	Arpav	0	0.48	0.50	0	1
If adjacent municipalities with drop-off and flat fee	Arpav	1	0.56	0.50	0	1
% Children aged 14 or younger	Istat	15.17	15.29	1.82	10.65	24.70
Population density	Istat	261.16	316.11	200.79	67.58	1512.99
% 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 on the (log) sorted waste ratio

Method: Panel OLS with Fixed Effects	(1)	(2)	(3)
PAYT	0.289***	0.243***	0.123***
	(0.044)	(0.043)	(0.044)
Additional years of PAYT			0.031***
			(0.010)
DtD		0.163***	0.152***
		(0.042)	(0.056)
Additional years of DtD			0.001
			(0.024)
If adjacent municipalities			0.092***
with DtD and PAYT			(0.035)
If adjacent municipalities			-0.111***
with drop-off and flat fee			(0.041)
PAYT × If adjacent municipalities			0.127*
with drop-off and flat fee			(0.068)
Log(population density)	0.974	1.194*	0.992
	(0.604)	(0.616)	(0.635)
% Children aged 14 or younger	0.051**	0.042*	0.042*
	(0.025)	(0.024)	(0.023)
% Adults aged 65 or older	0.005	0.015	0.013
	(0.024)	(0.024)	(0.023)
% Non-native residents	-0.013	-0.010	-0.012
	(0.013)	(0.013)	(0.013)
% Unemployment rate in the district	-0.004	-0.019	-0.049
	(0.034)	(0.033)	(0.044)
Year 1999	-0.444***	-0.313***	-0.271***
	(0.062)	(0.077)	(0.071)
Year 2000	-0.326***	-0.227***	-0.185***
	(0.048)	(0.056)	(0.052)
Year 2001	-0.188***	-0.143***	-0.141***
	(0.039)	(0.039)	(0.039)
Year 2002	-0.250***	-0.180**	-0.171**
	(0.085)	(0.086)	(0.079)
Year 2005	0.006	-0.010	-0.023
	(0.018)	(0.017)	(0.027)
Year 2006	0.016	-0.014	-0.057
	(0.044)	(0.043)	(0.075)
Year 2007	0.016	-0.014	-0.058
	(0.045)	(0.044)	(0.083)
Year 2008	0.018	-0.025	-0.097
	(0.068)	(0.069)	(0.129)
Constant	-2.160	-3.516	-2.213
	(3.598)	(3.649)	(3.786)
Observations	950	950	950
Number of municipalities	95	95	95
Fraction of variance due to ind. effects	0.895	0.925	0.907
R^2	0.098	0.077	0.103
R^2 within-group	0.658	0.673	0.689
F test for municipality effects	4.680	4.340	4.940
(pooled OLS vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]
Chi-squared test for random effects	51.980	55.330	106.800
(random-effects vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]

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

TABLE 3. Effects conditional on the initial sorted waste ratio

Sorters: *Method: Panel OLS with Fixed Effects*	**Weak** **(1)**	**Strong** **(2)**	**All** **(3)**
Previous (log) sorted waste ratio			0.543***
			(0.096)
PAYT	0.180**	0.117**	2.358***
	(0.077)	(0.045)	(0.458)
Additional years of PAYT	0.035**	-0.009	0.026***
	(0.016)	(0.008)	(0.006)
PAYT × Previous (log) sorted waste ratio			-0.564***
			(0.114)
DtD	0.031	0.160***	-0.165
	(0.097)	(0.035)	(0.637)
Additional years of DtD	-0.047*	0.014	-0.000
	(0.026)	(0.015)	(0.009)
DtD × Previous (log) sorted waste ratio			0.100
			(0.170)
If adjacent municipalities	0.206**	0.004	0.027
with DtD and PAYT	(0.080)	(0.040)	(0.033)
If adjacent municipalities	-0.217***	-0.017	-0.030
with drop-off and flat fee	(0.070)	(0.034)	(0.022)
PAYT × If adjacent municipalities	0.232**	-0.064	0.029
with drop-off and flat fee	(0.088)	(0.043)	(0.033)
Log(population density)	0.925	-0.375	-0.089
	(0.797)	(0.432)	(0.059)
% Children aged 14 or younger	0.078**	-0.036*	-0.014
	(0.033)	(0.018)	(0.015)
% Adults aged 65 or older	0.036	-0.011	0.005
	(0.043)	(0.018)	(0.009)
% Non-native residents	0.016	0.031***	0.006
	(0.020)	(0.008)	(0.005)
% Unemployment rate in the district	-0.067	-0.020	-0.033
	(0.044)	(0.036)	(0.021)
Year 1999	-0.554***	0.001	
	(0.129)	(0.054)	
Year 2000	-0.284***	-0.026	0.001
	(0.092)	(0.056)	(0.036)
Year 2001	-0.240***	-0.024	0.011
	(0.075)	(0.050)	(0.037)
Year 2002	-0.341**	0.122*	0.052
	(0.134)	(0.070)	(0.056)
Year 2005	-0.007	-0.027	-0.024*
	(0.029)	(0.018)	(0.014)
Year 2006	-0.049	-0.034	-0.040
	(0.070)	(0.042)	(0.032)
Year 2007	-0.039	-0.043	-0.054
	(0.074)	(0.043)	(0.035)
Year 2008	-0.070	-0.076	-0.070
	(0.110)	(0.066)	(0.053)
Constant	-2.915	6.636**	2.426***
	(5.042)	(2.702)	(0.596)
Observations	320	310	855
Number of municipalities	32	31	95
Fraction of variance due to ind. effects	0.896	0.874	
R^2	0.245	0.124	
R^2 within-group	0.841	0.740	
F test for municipality effects	3.740	5.330	
(pooled OLS vs. fixed-effects panel)	[0.000]	[0.000]	
Chi-squared test for random effects	33.140	32.710	
(random-effects vs. fixed-effects panel)	[0.001]	[0.001]	
Sargan test of over-identifying restrictions			81.782
(null hypothesis: restrictions are valid)			[0.961]

*Note: Column (1) refers to "weak sorters", with a sorting waste ratio lower than 37.680 as of 1999; Column (2) refers to "strong sorters", with a sorting waste ratio higher than 44.245 as of 1999. Standard errors clustered by municipality in round brackets; p-values in square brackets; *** p < 0.01, ** p < 0.05, * p < 0.1.*

TABLE 4. Effects of incentives on the type of waste

Waste (log of per capita kgs.)	**Sorted**	**Unsorted**		**Total**	
Sorters:	**All**	**All**	**All**	**Weak**	**Strong**
Method: Panel OLS with Fixed Effects	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
PAYT	0.124***	-0.203***	0.001	0.014	-0.095**
	(0.044)	(0.066)	(0.028)	(0.038)	(0.042)
Additional years of PAYT	0.024**	-0.042***	-0.007	-0.016	0.006
	(0.009)	(0.013)	(0.006)	(0.010)	(0.010)
DtD	0.050	-0.322***	-0.101***	-0.118***	-0.131***
	(0.044)	(0.057)	(0.021)	(0.040)	(0.026)
Additional years of DtD	-0.024	-0.029	-0.025***	-0.001	-0.071***
	(0.019)	(0.021)	(0.009)	(0.010)	(0.016)
If adjacent municipalities	0.099**	-0.046	0.007	0.075	-0.026
with DtD and PAYT	(0.040)	(0.042)	(0.023)	(0.053)	(0.039)
If adjacent municipalities	-0.060*	0.134**	0.051**	0.079**	-0.011
with drop-off and flat fee	(0.034)	(0.051)	(0.020)	(0.039)	(0.025)
PAYT × If adjacent municipalities	0.055	-0.121	-0.072**	-0.104**	0.059
with drop-off and flat fee	(0.062)	(0.077)	(0.031)	(0.050)	(0.041)
Log(population density)	0.213	-1.567***	-0.779***	-0.821**	-0.569
	(0.538)	(0.576)	(0.288)	(0.338)	(0.669)
% Children aged 14 or younger	0.034	-0.024	-0.008	-0.014	0.026
	(0.022)	(0.023)	(0.011)	(0.018)	(0.021)
% Adults aged 65 or older	0.008	-0.007	-0.005	-0.043***	0.004
	(0.023)	(0.026)	(0.014)	(0.014)	(0.028)
% Non-native residents	-0.010	0.002	0.002	-0.003	0.004
	(0.012)	(0.011)	(0.006)	(0.009)	(0.012)
% Unemployment rate in the district	0.004	0.059	0.053**	0.066*	0.078*
	(0.041)	(0.047)	(0.024)	(0.036)	(0.043)
Year 1999	-0.453***	-0.050	-0.183***	-0.094	-0.223***
	(0.070)	(0.067)	(0.036)	(0.074)	(0.069)
Year 2000	-0.316***	-0.007	-0.131***	-0.059	-0.165**
	(0.054)	(0.062)	(0.034)	(0.070)	(0.066)
Year 2001	-0.218***	0.032	-0.077***	-0.028	-0.128***
	(0.047)	(0.049)	(0.026)	(0.048)	(0.045)
Year 2002	-0.193**	0.059	-0.022	0.015	-0.157*
	(0.077)	(0.083)	(0.039)	(0.060)	(0.084)
Year 2005	0.016	0.046*	0.039***	0.016	0.089***
	(0.023)	(0.028)	(0.014)	(0.013)	(0.022)
Year 2006	0.079	0.120	0.136***	0.108***	0.248***
	(0.063)	(0.072)	(0.036)	(0.038)	(0.058)
Year 2007	0.098	0.153*	0.156***	0.113***	0.289***
	(0.069)	(0.079)	(0.040)	(0.039)	(0.066)
Year 2008	0.146	0.242**	0.243***	0.197***	0.434***
	(0.107)	(0.119)	(0.059)	(0.067)	(0.094)
Constant	3.463	14.170***	10.280***	11.190***	8.482**
	(3.246)	(3.409)	(1.737)	(2.065)	(4.136)
Observations	950	950	950	320	310
Number of municipalities	95	95	95	32	31
Fraction of variance due to ind. effects	0.608	0.964	0.969	0.978	0.958
R^2	0.437	0.005	0.212	0.322	0.175
R^2 within-group	0.685	0.749	0.199	0.318	0.321
F test for municipality effects	9.980	12.750	25.930	27.430	19.850
(pooled OLS vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Chi-squared test for random effects	53.600	113.400	106.280	30.540	48.550
(random-effects vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]

*Note: Column (4) refers to "weak sorters", with a sorting waste ratio lower than 37.680 as of 1999; Column (5) refers to "strong sorters", with a sorting waste ratio higher than 44.245 as of 1999. Standard errors clustered by municipality in round brackets; p-values in square brackets; *** p < 0.01, ** p < 0.05, * p < 0.1.*

TABLE 5. Effects of incentives only for towns in a consortium

Dependent Variable (in logs)	Per Capita Sorted Waste	Per Capita Total Waste	Sorted waste ratio		
			All sorters	Weak sorters	Strong sorters
Method: Panel OLS with Fixed Effects	(1)	(2)	(3)	(4)	(5)
PAYT	0.117**	0.007	0.110**	0.156*	0.124***
	(0.045)	(0.029)	(0.045)	(0.078)	(0.044)
Additional years of PAYT	0.022**	-0.005	0.028***	0.019	-0.009
	(0.010)	(0.007)	(0.010)	(0.020)	(0.008)
DtD	0.050	-0.105***	0.155**	0.040	0.153***
	(0.049)	(0.024)	(0.062)	(0.102)	(0.040)
Additional years of DtD	-0.019	-0.026**	0.007	-0.026	0.025
	(0.022)	(0.010)	(0.026)	(0.035)	(0.015)
If adjacent municipalities	0.101**	0.008	0.093**	0.185**	0.027
with DtD and PAYT	(0.044)	(0.025)	(0.037)	(0.087)	(0.043)
If adjacent municipalities	-0.069*	0.056**	-0.125**	-0.249***	-0.017
with drop-off and flat fee	(0.040)	(0.024)	(0.049)	(0.079)	(0.038)
PAYT × If adjacent municipalities	0.059	-0.074**	0.132*	0.245**	-0.064
with drop-off and flat fee	(0.064)	(0.033)	(0.071)	(0.092)	(0.046)
Log(population density)	0.252	-0.774**	1.026	0.975	-0.567
	(0.582)	(0.310)	(0.685)	(0.774)	(0.393)
% Children aged 14 or younger	0.033	-0.011	0.044*	0.083**	-0.039*
	(0.024)	(0.011)	(0.025)	(0.034)	(0.019)
% Adults aged 65 or older	0.007	-0.009	0.016	0.047	-0.027
	(0.025)	(0.015)	(0.025)	(0.047)	(0.016)
% Non-native residents	-0.011	0.003	-0.014	0.008	0.031***
	(0.013)	(0.007)	(0.014)	(0.023)	(0.009)
% Unemployment rate in the district	-0.001	0.054**	-0.055	-0.067	-0.040
	(0.044)	(0.025)	(0.047)	(0.045)	(0.039)
Year 1999	-0.470***	-0.179***	-0.291***	-0.564***	-0.015
	(0.075)	(0.037)	(0.076)	(0.136)	(0.060)
Year 2000	-0.302***	-0.129***	-0.173***	-0.275**	-0.032
	(0.058)	(0.035)	(0.057)	(0.102)	(0.064)
Year 2001	-0.222***	-0.070***	-0.152***	-0.230**	-0.036
	(0.051)	(0.026)	(0.044)	(0.087)	(0.055)
Year 2002	-0.175**	-0.006	-0.169**	-0.353**	0.130*
	(0.082)	(0.038)	(0.084)	(0.138)	(0.074)
Year 2005	0.012	0.038**	-0.026	-0.016	-0.034*
	(0.025)	(0.015)	(0.029)	(0.031)	(0.017)
Year 2006	0.068	0.135***	-0.067	-0.057	-0.057
	(0.069)	(0.038)	(0.080)	(0.075)	(0.043)
Year 2007	0.085	0.153***	-0.068	-0.050	-0.066
	(0.076)	(0.042)	(0.090)	(0.081)	(0.043)
Year 2008	0.131	0.244***	-0.113	-0.087	-0.115*
	(0.116)	(0.063)	(0.138)	(0.121)	(0.067)
Constant	3.299	10.340***	-2.438	-3.416	8.101***
	(3.508)	(1.875)	(4.092)	(4.947)	(2.455)
Observations	865	865	865	307	276
Number of municipalities	91	91	91	31	29
Fraction of variance due to ind. effects	0.605	0.969	0.908	0.903	0.930
R^2	0.448	0.223	0.098	0.231	0.054
R^2 within-group	0.682	0.197	0.686	0.842	0.739
F test for municipality effects	8.820	23.490	4.540	3.320	6.000
(pooled OLS vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Chi-squared test for random effects	54.870	101.850	99.760	26.450	31.250
(random-effects vs. fixed-effects panel)	[0.000]	[0.000]	[0.000]	[0.009]	[0.003]

*Note: Column (4) refers to "weak sorters", with a sorting waste ratio lower than 37.680 as of 1999; Column (5) refers to "strong sorters", with a sorting waste ratio higher than 44.245 as of 1999. Standard errors clustered by municipality in round brackets; p-values in square brackets; *** p < 0.01, ** p < 0.05, * p < 0.1.*

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

FIGURE 1. Dynamics of policy management
Municipalities implementing a given policy (%)

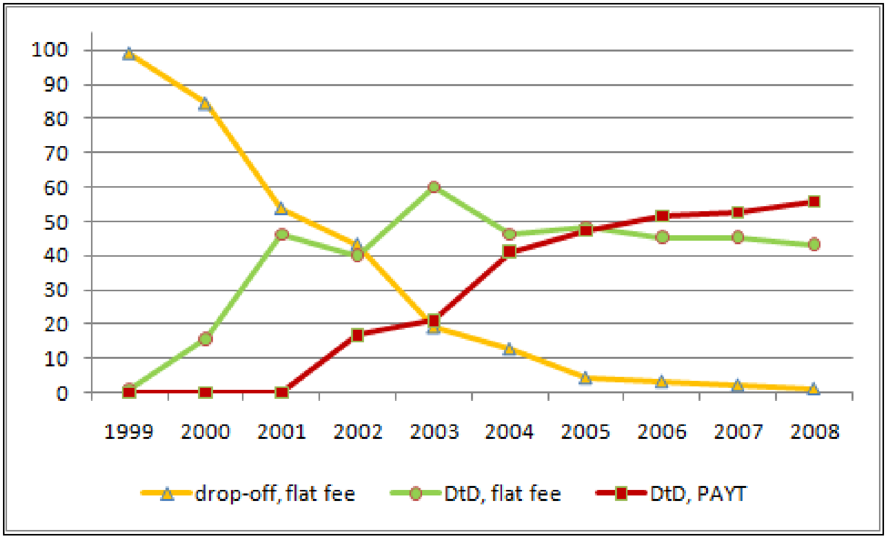


FIGURE 2. Dynamics of the sorted waste ratio (%).

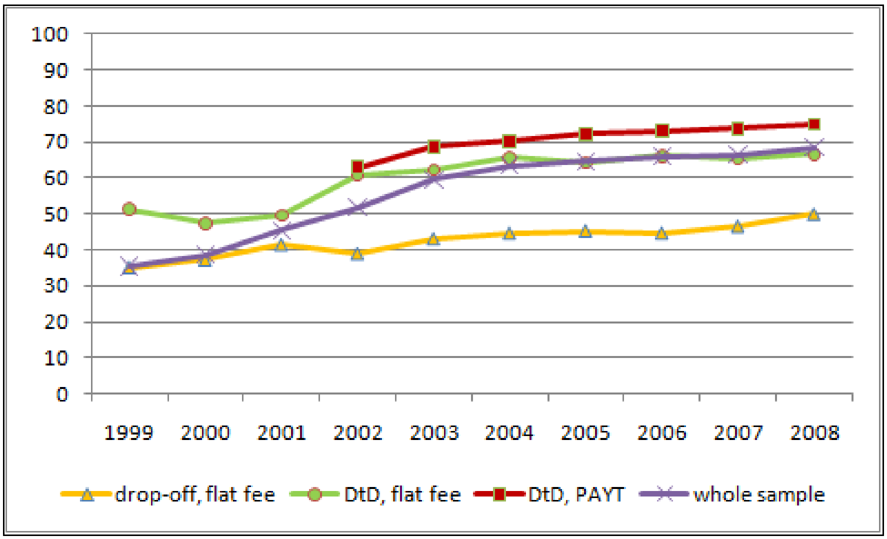


FIGURE 3. Effects on the sorted waste ratio by initial sorted waste ratio

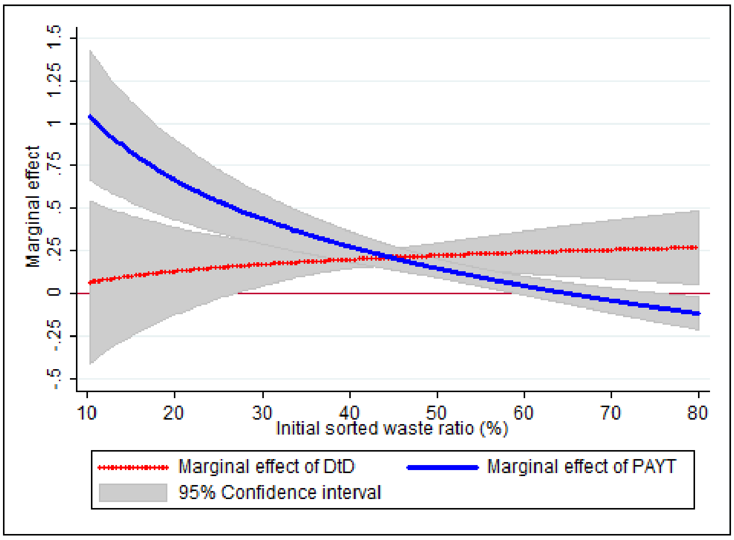


FIGURE A.1. The Veneto region (light colour) and the district of Treviso (dark colour) in Italy

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

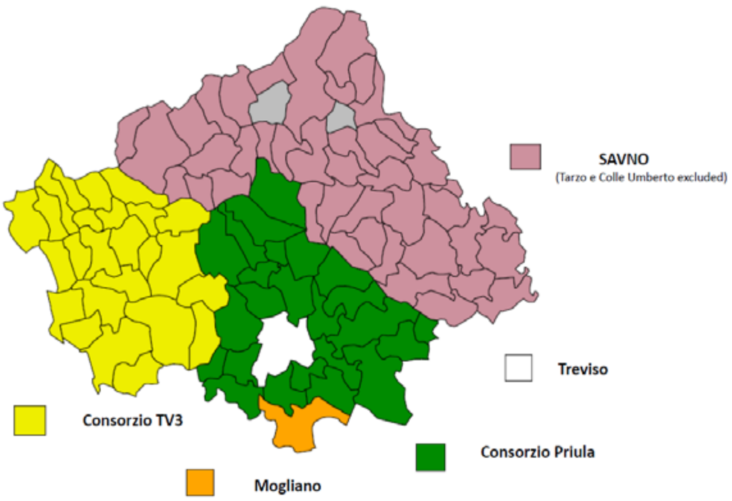


FIGURE A.3. Trends in the percentage of municipalities joining a consortium

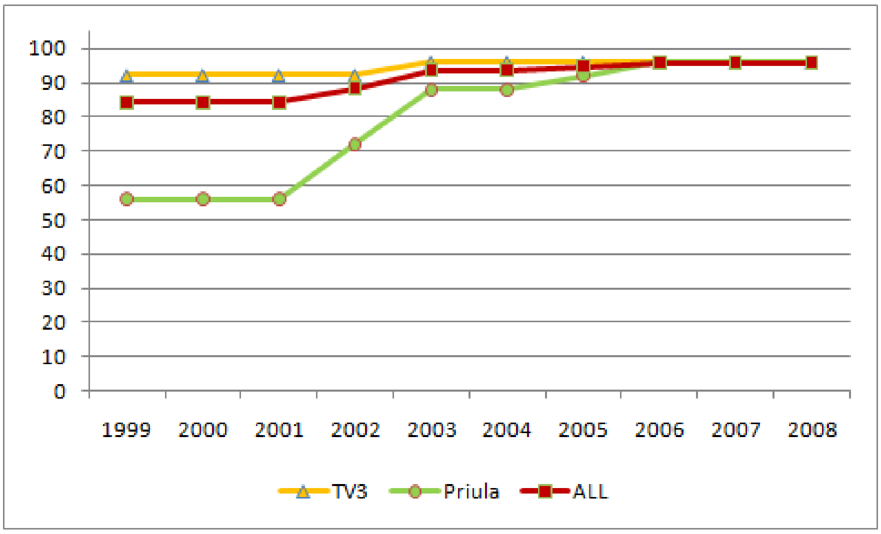


FIGURE B.1. A drop-off point for sorted and unsorted waste

FIGURE B.2. Carts and bins for organic waste and unsorted waste in Priula

FIGURE B.3. DtD collection calendar in Priula

	WHAT	WHEN
	unsorted 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

FIGURE B.4. A transponder for the identification of unsorted waste production

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

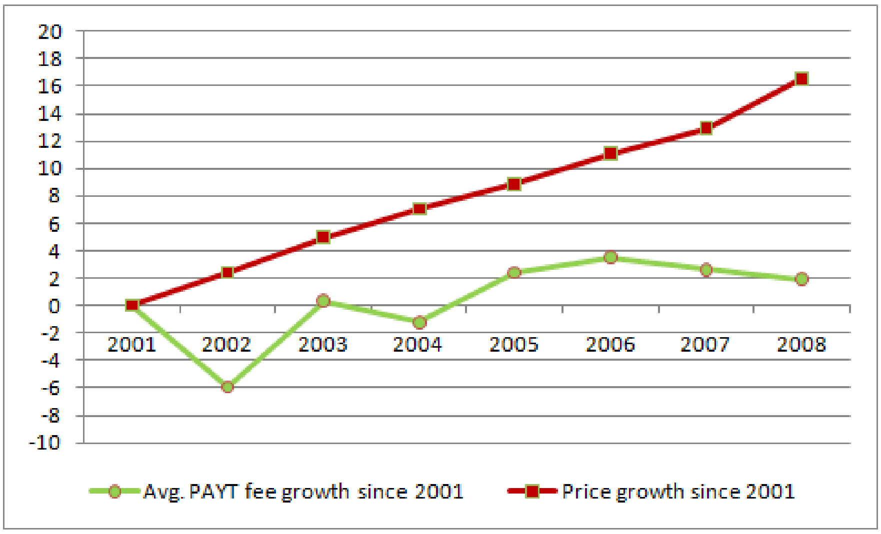
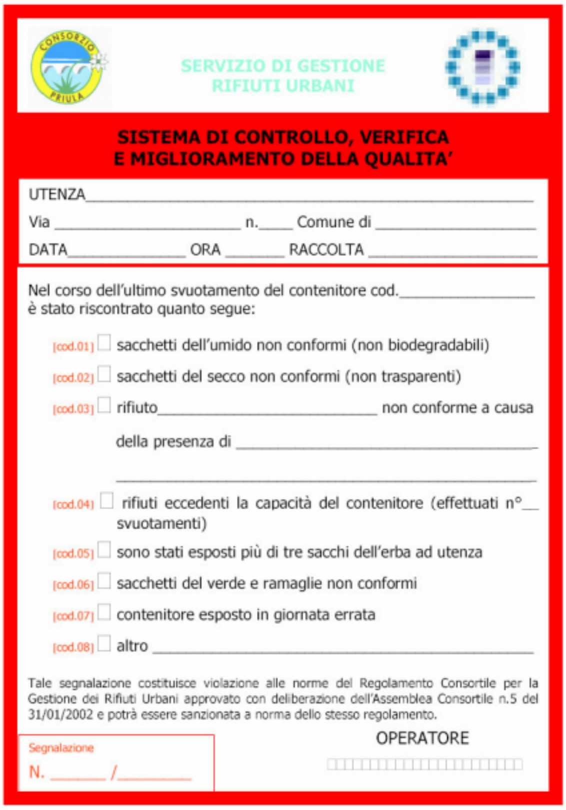


FIGURE B.6. The report sheet used in Priula to signal irregularities in waste sorting


CONSORZIO PRIULA

SERVIZIO DI GESTIONE
RIFIUTI URBANI

SISTEMA DI CONTROLLO, VERIFICA
E MIGLIORAMENTO DELLA QUALITA'

UTENZA____
Via _____________________ n.____ Comune di __________________
DATA_______________ ORA ________ RACCOLTA _________________

Nel corso dell'ultimo svuotamento del contenitore cod.________________
è stato riscontrato quanto segue:

[cod.01] ☐ sacchetti dell'umido non conformi (non biodegradabili)

[cod.02] ☐ sacchetti del secco non conformi (non trasparenti)

[cod.03] ☐ rifiuto___________________________ non conforme a causa
della presenza di ___________________________________
____

[cod.04] ☐ rifiuti eccedenti la capacità del contenitore (effettuati n°__ svuotamenti)

[cod.05] ☐ sono stati esposti più di tre sacchi dell'erba ad utenza

[cod.06] ☐ sacchetti del verde e ramaglie non conformi

[cod.07] ☐ contenitore esposto in giornata errata

[cod.08] ☐ altro ____

Tale segnalazione costituisce violazione alle norme del Regolamento Consortile per la Gestione dei Rifiuti Urbani approvato con deliberazione dell'Assemblea Consortile n.5 del 31/01/2002 e potrà essere sanzionata a norma dello stesso regolamento.

Segnalazione
N. ________ /__________

OPERATORE