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PAY AS YOU THROW: EVIDENCE ON THE INCENTIVE TO RECYCLE

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JEL Classification: D01, D78, Q53

Keywords: Pay as you throw, Municipal Waste Management, tariff, incentive, Synthetic control

Pay as you throw: evidence on the incentive to recycle

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Abstract

The Pay as you throw (PAYT) system implies that people pay according to the unsorted waste they produce. Its impact has been studied with mixed results on total waste and recycling because the estimates refer to different socio-economic contexts and so do not take into account all time-varying effects of unobservables. A way out of this problem is to use the Synthetic Control Method (SCM), which is a data driven impact evaluation. In particular, in our work we apply the SCM to the municipality of Ferrara where users pay a fee up to a given number of bags produced, after this number they are charged for every additional bag. We test the impact of the introduction of this system in the municipality of Ferrara in July 2017, by using a sample of municipalities of the same region served by the same firm. We find that the introduction of the new tariff strongly increased waste recycling and strongly decreased Ferrara's total waste with respect to its synthetic counterfactual. In fact, after one year of the implementation of the new tariff, Ferrara has increased its waste recycling percentage of total waste by 40% and decreased the total per capita waste by 30% with respect to what its synthetic counterfactual has done.

Keywords*:* Pay as you throw, Municipal Waste Management, tariff, incentive, Synthetic control.

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Introduction

The standard approach to waste tariffs envisages a fixed rate that is usually based on the size of the household and\or on the size of the house. Based on a Pigouvian tax approach (Pigou, 1920), an increasing number of communities has adopted a variable rate pricing model aiming at reaching an efficient level of Municipal solid waste. There were many cases in the 80s in US where this method was introduced[2] (Kinnaman, 2006). Afterwards, the pay as you throw (PAYT) system was implemented in many European countries, particularly in Switzerland, the Netherlands, the northeastern area of Germany, Denmark and in Italy (Reichenbach, 2008). The reason underpinning the use of the PAYT system is that citizens must feel the marginal cost of a unit more of produced mixed waste and so of a unit less of waste recycling to the extent that the two phenomena are linked. The method to do so is to use a unit price tariff for the mixed waste: citizens pay according to the quantity of mixed waste they produce. Testing the impact of the introduction of the tariff is extremely relevant to understand if it can increase the rate of circularity of the economy by converting waste into new products (recycling) and/or decrease the amount of total waste produced. As regards total waste per capita, there is in fact a need for reduction, given that in OECD countries it has remained stable at around 500 kg per capita over the last 20 years (Figure 1). Nevertheless, recycling has doubled over the last 20 years in OECD countries, passing from 80 kg to 139 kg per capita (Figure 1). Since we have been using the PAYT system, introduced since the 80s, does it imply this last increase in recycling? Moreover, could the PAYT system also work in reducing total waste per capita, which does not seem to have been reduced in aggregate? Answering these questions is also important if we want to understand how the PAYT system can contribute to reaching the EU target regarding waste recycling, which should be 60% of total waste by 2030.

[INSERT FIGURE 1 AROUND HERE]

Even though the literature generally estimates negative average effects on unsorted waste due to the introduction of the PAYT system, there is no consensual evidence on

[2] The example most known is that of the city of Marietta (US) in 1994 where two kinds of unit price tariffs were introduced. According to the first, citizens paid by buying bags in which to throw their mixed waste, with the other method citizens bought cans to fill with waste. According to Van Houtven et al. (1999), the first method was much more incentivizing in recycling waste than the latter.

the behavioral mechanisms behind such reduction, i.e., on whether households adjust their behavior by increasing recycling and/or decreasing total waste. Checking for both mechanisms is important because in the first case the resources quota devoted to circular economy increases, the second case reveals that before the introduction of the tariff, waste was excessive with respect to the case when citizens feel the marginal cost of producing it and so it was inefficiently produced. Existing results vary depending on the method, data and municipalities under study. For example, a statistically significant waste reduction of different magnitude but a not statistically significant effect on recycling are found, for the U.S., in Jenkins et al. (2003), Fullerton and Kinnaman (1995, 1996) and Wright et al. (2019), for the Netherlands, in Allers and Hoeben (2010). Instead, Carattini et al. (2018) find a positive effect on the frequency of recycling for Switzerland. For Korea, Hong and Adams (1999) estimate positive effects on recycling, but no source-reductions. For Japan, Usui and Takeuchi (2014) find long-run increases in recycling and only short-run total waste reductions. For Italy Bucciol et al. (2015) for the years 1999–2008, using a panel regression analysis for 95 municipalities in the district of Treviso, estimate that the PAYT system increases the sorted-to-total waste ratio by 17% and decreases the total waste per capita by 3%.

These mixed results can be because the estimates refer to different socio-economic contexts and different starting levels of recycling and so do not take all time-varying effects of unobservables into account. A way out of this problem is to use the Synthetic Control Method (SCM), which is a data-driven impact evaluation. Bueno and Valente (2019), using SCM, study the effects of the introduction of a unit pricing system on the waste, consisting in a fee per given amount of unsorted waste, in the municipality of Trento, having as counterfactual a pool of other similar Italian cities without the PAYT system belonging to different regions and served by different firms. They find a strong effect on the level of unsorted waste; however, the effect on waste recycling seems to be negligible. In our work, we also use the SCM with a more homogenous sample since all the municipalities belong to the Emilia Romagna region and are served by the same multi-utility. This is very important because all municipalities analyzed have the same regional rules on waste management, and given that they are served by the same multi-utility, it is possible to compare treated and control municipalities to which the same technology of waste collection is applied. In fact, if we compare municipalities where different multi-utilities operate it would be possible that a difference between the treated and control group would capture an improvement in the technology adopted by the operating multi-utility and not the behavioral response of the citizens to the introduction of a new tariff. Moreover, the PAYT tariff of Ferrara differs from that of Trento. In fact, in Ferrara citizens can throw unsorted waste without paying an additional fee up to a given amount per month; after that any additional amount of waste is charged with a per unit fee. Contrary to Bueno and Valente (2019) and consistent with Bucciol et al. (2015), we find that the introduction of the new tariff increased waste recycling in Ferrara with respect to its synthetic model. We also find that the total waste decreased but at a lower rate. In fact, after one year of the implementation of the new tariff Ferrara increased its waste recycling percentage of total waste with respect to its synthetic counterfactual by 40%. This is a strong increase also with respect to the result found in Bucciol et al. (2015) which was 17%. The total waste decreased with respect to its synthetic counterfactual by 30%. The different result for recycling with respect to Bueno and Valente (2019) could be driven, among other factors, by the fact that Ferrara, before the introduction of the tariff, had a lower level of waste recycling (40% of recycling of total waste), than Trento[3] (67% of recycling of total waste): this means that there could be a technological threshold of recycling beyond which it is difficult to go. Hence if this threshold is reached the introduction of the tariff hinges only on the level of total waste: citizens will throw things only when it is strictly necessary if the PAYT system is applied.

The paper is organized as follows: Section 2 describes the institutional settings of waste management and the PAYT tariff adopted in Ferrara, Section 3 contains the description of data, the empirical methodology used and empirical analysis, in Section 4 there are the results of the main specifications, Section 5 contains the heterogeneity analysis, in Section 6 we carry out the placebo tests for the main specification and Section 7 concludes.

2. Institutional setting

The Environmental Code[4] in Italy is the main national law on waste management. It deals with different authorities regarding waste management, assigning specific responsibilities to different institutional levels. In particular, regions have a coordinating

[3] https://www.comune.trento.it/Aree-tematiche/Ambiente-e-territorio/Rifiuti-urbani/Gestione-integrata-rifiuti/Raccolta-differenziata/Risultati-raggiunti

[4] Legislative Decree n. 152/2006.

role, through the development of a Regional Plan, which contains both policies specific to the regions, general rules and main goals for waste management by municipalities (Tornavacca, 2015). Then municipalities are the authorities that concretely choose the management system and all the policies in order to address targets fixed by the highest-level authorities (Bonelli et al., 2016).

Waste collection in Ferrara, managed since 2004 by Hera S.p.A.[5], was financed until 2014 through the TARES[6], which is a tariff that fully covers the costs of the collection and disposal service: the total amount of this tariff mainly depends only on the surface area of properties and the composition of the family.

With the City Council Resolution n.6/2014, Ferrara decided to introduce the PAYT system with a radical change in the municipal waste-collection law. Following feasibility studies and experimentation in the small village of Pontelagoscuro[7], the PAYT system introduced in the Municipality of Ferrara was organized in a mixed structure. For the urban residential areas, bins were provided for waste recycling and bins equipped with an electronic cover for unsorted waste. For the rural area a curbside collection system has been implemented with the presence of garbage cans, a kind of personal bins, different by type of waste, delivered to each user.

In the urban area, each user has been provided with an electronic card. This card allows the opening of the cover of the bin where the unsorted waste can be thrown. Each card is matched to only one user. Each access to the electronic cover corresponds to 30 liters of unsorted waste. The system is replicated in the areas served by curbside collection, with the difference that the identification of the user takes place through the scanning of the bar code on the personal bin, which corresponds to 40 liters.

For the entire municipal area, six months of tests were scheduled, starting from July 2017, during which the electronic card was provided and the bins with user codes and

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[5] Agreement stipulated between the Optimal Territorial Area Authority of Ferrara (AATO6) and Hera S.p.A (2004). Hera is one of the largest multi-utilities in Italy and operates mainly in the environment sector (waste management), in the water sector (aqueducts, sewers and purification) and in the energy sector (especially gas, distribution and sale of electricity).

[6] TARES was introduced with the Decree n. 201/2011.

[7] The results of the feasibility studies were subsequently confirmed by the experimentation, started in November 2016, in the municipal village of Pontelagoscuro (5.600 inhabitants, in the northern area of the city) where, after a relatively short time (one year), the result of 70% of differentiated waste was recorded, as reported in the minutes of the meeting of the IV Council Commission of the municipality of Ferrara on 11 May 2017.

the electronic cover were activated. Starting from January 1st 2018, the quota of the tariff for waste collection, in the municipality of Ferrara, is calculated using the PAYT system. In particular, the part of the tariff[8] computed using the PAYT system is given by the product of the liters of unsorted waste minus a minimum threshold and the unit cost of the service (in 2019 it was 0.055 € / liter).

3. Empirical analysis

3.1. Identification: Synthetic Control Method

In appendix B, we describe the SCM used to test how after July 2017 the PAYT tariff impacted on waste recycling and total waste. Abadie and Gardeazabal (2003) first used this empirical methodology. This is based on the principle of building a reference comparison unit as an "artificial counterfactual" (called synthetic control), which is then used as a reference for comparison to the real treated unit (Abadie, Diamond and Hainmueller, 2015; and for a recent review, see Abadie, 2019).

In particular, a set of units with the same features as the treated one constitutes a "donor pool" for the construction of the artificial unit. This unit is built as a weighted average of some pre-intervention characteristic variables, chosen to resemble the treated unit before the treatment; the calculated weights are then applied to the outcome variable under analysis for the post-treatment period. The post-treatment performance of the control group represents the performance of the treated unit if the real-life intervention had not occurred.

Compared to a regression-based approach, the synthetic control method has the fundamental advantage of explicitly showing to what extent each unit has contributed to the counterfactual (Abadie Diamond and Hainmueller, 2010, 2015). Otherwise, a direct comparison of Ferrara's performance with that of another single town may not be sufficiently accurate, since it may capture the effects not only of the tariff, but also from other different shocks which may have impacted our outcome variables as well.

3.2. Data Sample and Empirical Strategy

In order to apply a synthetic control method, we use all the municipalities served by Hera in the Emilia Romagna region and not affected by the introduction of a PAYT

[8] For a complete description of the tariff see appendix A.

tariff, which are 36[9], as the "donor pool". Given the short timespan since January 2015, we use high-frequency data. In particular, we use a panel dataset spanning the months from January 2015 to December 2018. Therefore, we have 48 months, with 18 months after the introduction of the PAYT system. We run four iterations of the SCM, using as outcome variables the quota of waste recycling of total waste, the total waste per capita, the quota of organic waste recycling of total waste and that of multimaterial waste recycling (including paper, paperboard, plastic, metal, wood and glass) of total waste (Table 1). Data on the quantities of waste produced are provided by Hera through the management platform of the supra-municipal waste disposal plants O.R.S.O.

We use 9 socio-economic variables as predictors for Ferrara pre-intervention characteristics, which are annual variables taken before the beginning of the pre-treatment period (Table 2). As Johnstone and Labonne (2004), we control for economic and demographic determinants of household municipal solid waste: per capita income (average 2015-2016), quota of firms in the service industry (2015-2016), number of firms per capita (2015-2016), quota of population over 65 (2015-2016) and density (2015-2016). Educated citizens may have greater preference for a clean environment (Kinnaman and Fullerton, 2000), so we use as pre-treatment control the quota of educated people in 2011. In addition, social capital has an important positive impact on local waste recycling (Tsai, 2008), so we add, as a proxy of the municipal social capital, the quota of volunteers in 2011 and the turnout in the 2011 referendum[10]. Finally, the tourist population may have a lower propensity to separate collection, as they are not directly interested in the environmental impact on the municipality (Mateu-Sbert et al., 2013), hence we include the number of per-capita hotels (2015-2016). These data were obtained from the Italian National Institute of Statistics (Istat), the Revenue Agency - Ministry of Economy and Eligendo - Ministry of the Interior.

[INSERT TABLE 1 AROUND HERE]

[INSERT TABLE 2 AROUND HERE]

In addition, following Abadie, Diamond and Hainmueller (2010), we also include four lags of the dependent variable, 6, 12, 18 and 24 months before the introduction of the tariff, to more accurately replicate by means of the "artificial counterfactual" the treated

[9] The list of the municipalities is reported in Appendix C.
[10] The 2011 referendum also referred to local public services, such as urban waste collection.

town before treatment. Once the synthetic control weights are obtained, they are then applied to the outcome variables for the whole period of analysis in order to obtain the counterfactual post-treatment Ferrara behavior. Finally, the synthetic control dependent variable is compared with the corresponding variable for the real Ferrara to correctly test the relevance of the treatment.

4. Basic Results

We analyze the impact on the waste recycling quota and the total waste per capita. In the heterogeneity section we split waste recycling into the organic recycling quota and the multimaterial recycling quota[11].

4.1 Recycling waste quota

If we focus on the recycling waste quota, the synthetic Ferrara emerges as a combination of the municipalities of Cervia (weight=2.6%), Cesena (17.7%), Faenza (64.7%) and Lugo (15%). As ~~it~~ is shown in Table 3, the choice of weights releases exogenous variables, which are very similar in the treated and the synthetic, and different from the simple average with the whole donor pool.

[INSERT TABLE 3 AROUND HERE]

The town of Faenza is the one which most closely resembles the Ferrara waste recycling quota over the pre-treatment period. From Figure 2~~,~~ we conclude that the recycling quota of the synthetic Ferrara mimicks perfectly that of the real Ferrara before the introduction of the tariff and that it does differ from that of the real Ferrara after the introduction of the tariff, this being much higher than the previous one. The shaded area (Born, Müller, Schularick and Sedláček, 2019) is plus/minus one standard deviation of the difference between synthetic Ferrara and real Ferrara before the introduction of the tariff. Thus this area gives an upper and a lower limit of an interval inside which the real Ferrara could fall if it had been in the pre-treatment period. Waste recycling was around 45% before the introduction of the tariff for both real and synthetic Ferrara with a drop to 25% in 2017, and after the introduction of the tariff the synthetic Ferrara stayed around 26-27% and the real Ferrara arrived at 70% in one year.

[11] The results for waste recycling per capita as dependent variable are available upon request.

After the introduction of the PAYT tariff, the line of the real Ferrara lies outside the shaded area, and before the introduction, it lies inside the shaded area almost all of the time. Hence, this suggests there has been an impact on waste recycling.

[INSERT FIGURE 2 AROUND HERE]

The quantitative results can be seen in Table 4: eighteen months before the introduction of the tariff, the quota of waste recycling lies within the upper/lower bound interval for the synthetic Ferrara, with some few exceptions, implying that there is no significant difference between the real and the synthetic Ferrara. In contrast, during the eighteen months after the tariff, the waste recycling quota lies outside this interval (stressed in italics in the table); in particular, it lies above the upper boundary, indicating there is a significant increase in the real Ferrara with respect to its benchmark. This positive impact remains stable during all 2018.

[INSERT TABLE 4 AROUND HERE]

When we compute the difference of the recycling quota in percentage points with respect to the month of the introduction of the tariff between the synthetic Ferrara and the real Ferrara (Table 5), we find that this is 5 p. p. after the introduction of the tariff rising to 30 p.p. in December 2017. In January 2018, people started paying according to the new tariff and from this date, there was a jump to around 40 p.p., which remained stable throughout 2018, reaching a peak of 44 p. p. in August.

[INSERT TABLE 5 AROUND HERE]

4.2 Total waste per capita

The introduction of the PAYT could also decrease the absolute level of waste production, as already shown in Bueno and Valente (2019). Using the total waste per capita, the synthetic control is made up of the municipalities of Imola (weight=31.1%), Faenza (23%), Cesena (17.2%), Sant'Agata sul Santerno (15.4%), Premilcuore (6.9%), Gambettola (3.3%), Santa Sofia (2.7%) and Roncofreddo (0.5%).

Analyzing the averages of the differences of the control variables (Table 6), we verify that the difference between Ferrara and the synthetic Ferrara is much smaller than the difference we would have comparing Ferrara with the average of all municipalities for the "donor pool".

[INSERT TABLE 6 AROUND HERE]

Figure 3 shows that before the introduction of the PAYT the trend of total waste production is very similar in Ferrara and the synthetic control. After July 2017, the date of the introduction of the PAYT system, the total waste per capita in Ferrara started to decrease, while we do not observe the same trend for the synthetic control. The Ferrara line lies outside the shaded area after the introduction of the tariff except for the first few months, confirming that after the introduction of the PAYT tariff in the real Ferrara there is a significant decrease in the production of total waste with respect to the synthetic control.

[INSERT FIGURE 3 AROUND HERE]

To quantify the effect for the total waste, we compute the difference in percentage points with respect to the introduction of the tariff between the synthetic Ferrara and the real Ferrara (Table 7). We find that this difference is very small in the first months after the introduction of the PAYT system. Starting from January 2018, when people started paying according to the new tariff, the difference registered a jump to around 20 p.p., reaching a peak of 32 p. p. in July 2018.

[INSERT TABLE 7 AROUND HERE]

5. Heterogeneity

We analyze the results by splitting waste recycling into two kinds: organic and multimaterial.

5.1. Organic recycling

We replicate the previous analysis by using the organic recycling quota of total waste.

In this case, the weights are the following: Lugo (38.5%), Ravenna (34.8%), Cesena (12.5%), Premilcuore (11%) and Santa Sofia (3.2%). Hence, the municipalities of Lugo and Ravenna are those, which most closely resemble Ferrara in organic waste recycling quotas over the pre-treatment period.

Table 8 shows controls variables for Ferrara and the synthetic Ferrara. Also in this case the difference between them is much smaller than the difference we would have comparing Ferrara with the average of all municipalities served by Hera.

[INSERT TABLE 8 AROUND HERE]

From Figure 4 we conclude that the organic recycling quota of the synthetic Ferrara mimicks perfectly that of the real Ferrara before the introduction of the tariff and it differs from that of the real Ferrara after the introduction of the tariff, this being much higher than the previous one. Organic waste recycling was around 13% before the introduction of the tariff for both real and synthetic Ferrara and after the introduction the tariff the synthetic Ferrara stayed around 13-15% and the real Ferrara arrived at more than 40% in one year.

[INSERT FIGURE 4 AROUND HERE]

5.2. Multimaterial recycling

We replicate the previous analysis by using the multimaterial recycling quota of total waste. In this case the weights are Sant'Agata sul Santerno (32.7%), Cesena (28%), Faenza (13.3%), Bagno di Romagna (8.7%), Premilcuore (6.5%), Gambettola (4.6%), Ravenna (2.9%), Lugo (2.1%) and Imola (1.5%). Hence, the municipalities of Sant'Agata sul Santerno and Cesena are those, which most closely resemble Ferrara in the multimaterial waste recycling quota over the pre-treatment period.

Table 9 also sheds light on the fact that using the synthetic control method allows us to have exogenous variables of the treated and the synthetic town that are more similar than if we use the average of all municipalities served by Hera.

[INSERT TABLE 9 AROUND HERE]

From Figure 5 we conclude that also in this case the multimaterial recycling quota of the synthetic Ferrara mimicks perfectly that of the real Ferrara before the introduction of the tariff and that it differs from that of the real Ferrara after the introduction of the tariff, this being much higher than the previous one. The multimaterial waste recycling was between 40% and 30% with a drop to almost 13% in 2017 before the introduction of the tariff for both real and synthetic Ferrara and after the introduction of the tariff Ferrara it jumped to almost 30% during 2018 while the synthetic Ferrara stayed at 13%.

[INSERT FIGURE 5 AROUND HERE]

In Table 10, we compute the difference in percentage points with respect to the introduction of the tariff between the synthetic Ferrara and the real Ferrara, for organic waste and for multimaterial waste. For multimaterial waste, we find a lower effect of the introduction of the PAYT system than for organic waste. In fact, after the trial period (in which people did not pay according to the PAYT tariff even if the system with electronic cards had been implemented) the difference between Ferrara and the control group for the multimaterial waste quota is between 15 p.p. and 18 p.p., while for the organic waste quota between 25 p.p. and 30 p.p.

[INSERT TABLE 10 AROUND HERE]

6. Placebo Experiments

In this section, we run a set of robustness tests to validate our main result. We found some evidence of causality relative to the impact of the PAYT tariff on waste recycling in Ferrara, so we ran municipality and time placebo tests, changing respectively the treated municipality and the time of the shock. If we are certainly estimating a causal effect due to the introduction of the tariff, we expect not to find any effect in the placebo tests. First, we estimate the synthetic control for each of the municipalities in the donor pool while exposing them to the treatment. If our benchmark estimate picks up the causal effect of the introduction of the tariff, the divergence of municipal-specific synthetic controls from the respective data following the treatment date should be considerably smaller than in the case of Ferrara.

Table 13 shows the results of the municipal-placebo experiments for the waste recycling quota. In what follows (column 1 Table 11), we use the ratio between the post-and-pre-treatment of the root mean squared prediction error (RMSPE) so that the higher the ratio, the larger the difference between treated and synthetic in the post-treatment case with respect to the pre-treatment case. The RMSPE is equal to the square root of the mean of the square of the difference between the treated and the synthetic control before the treatment. The second column contains the RMSPE for the pre-treatment period, and the third one the RMSPE for the post-treatment period.

[INSERT TABLE 11 AROUND HERE]

Thus, column 1 of Table 11 quantifies how closely the municipal-specific synthetic controls follow the post-treatment data relative to the pre-treatment fit. Ferrara has a much larger ratio than all the other municipalities (17.696). However, there are also 19 municipalities whose coefficient is higher than one: Faenza, Castel Bolognese, Bagnacavallo, Imola, Gatteo, Conselice, Brisighella, Cesena, Santa Sofia, Cotignola, Bagno di Romagna, Ravenna, Cesenatico, Alfonsine, Russi Savignano del Rubicone, Bagnara di Romagna, Lugo, Verghereto and Gambettola.

A priori, this could be evidence of a spillover or mimicking effect due to the introduction of the tariff in Ferrara (Born, Müller, Schularick and Sedláček, 2019). If so, technically the assumption that the donor pool countries are unaffected by the treatment is potentially violated. To test the reliability of our results, we therefore restrict the donor pool to only those municipalities with a ratio below one. Qualitative results remain unchanged (see Figure 6).

[INSERT FIGURE 6 AROUND HERE]

In Figure 7 we plot the results of the difference between real and synthetic Ferrara versus spatial placebos. That is, we consider the possibility that each municipality is a treated municipality and take the difference with its corresponding synthetic. This Figure sheds lights on the sign of the difference between synthetic and real municipality. The bold line corresponds to the difference for Ferrara. The estimated trend for Ferrara is clearly positive after the treatment, and much higher than the estimated trend for the rest of the municipalities. Before the treatment, the series for Ferrara oscillates around zero and in any case does not show a noticeably different trend from the rest of the municipalities. Only in first months of the introduction of the PAYT system (when the tariff was not applied) are there some placebo differences that are higher than Ferrara, but from January 1st 2018 onwards the Ferrara difference is the largest.

[INSERT FIGURE 7 AROUND HERE]

We also ran another placebo experiment to test for the adequacy of the treatment month. To do so, we changed the treatment month to a period before the tariff had been implemented. In particular, we used 17 months before June 2017.

From Table 12 we can see that for the fake tariff introduction the ratio is always lower than 1, showing that the fake introduction of a tariff does not have any significant impact on the level of waste recycling in Ferrara with respect to its synthetic counterfactual.

[INSERT TABLE 12 AROUND HERE]

We further repeated the SCM estimate by excluding one town from the donor pool one by one. As can be seen from Figure 8, the difference between the real and the synthetic Ferrara remains the same as in the main specification.

[INSERT FIGURE 8 AROUND HERE]

7. Conclusions

Waste recycling is a very hot issue. The way to do it is matter of discussion. The introduction of a PAYT system has been adopted worldwide. The literature does not show unique results on the effectiveness of PAYT in increasing waste recycling. This is because studies refer to particular socio-economic environments which are very different from each other. Moreover, the empirical methodology could also affect the results. In particular, many studies use cross-section datasets and even when panel datasets are used, time varying unobservables are not taken into account. A way out ~~to~~ of this last problem is to use SCM, as we did. In fact, we tested the effectiveness of the PAYT system introduced in July 2017 in the town of Ferrara, using municipalities of the same region served by the same multi-utility as a donor pool. We find that the introduction of the PAYT tariff has increased the recycling waste quota of Ferrara with respect to the synthetic Ferrara by 40%. This result is in sharp contrast with the result obtained by using the same methodology for Trento (Bueno and Valente, 2019), where the adoption of the PAYT system had a negligible effect on the waste recycling. The result we found is due 25% to organic waste and 15% to multimaterial (glass, plastic and paper) waste. As in Bueno and Valente (2019), we found an important decrease (30%) in the production of total waste after the introduction of the new tariff. Moreover, our results are robust in terms of spatial and time placebo tests. The spatial tests are conducted by replacing the treated town with all the other municipalities in the donor pool and in the time placebo test we replace the treatment month with the previous 17 months.

Overall, from our analysis we can conclude that the PAYT system - that is closer to a Pigouvian taxation in contrast to the previous tariff system not linked to the unsorted waste produced – is extremely effective in creating incentives to waste recycling and reducing total waste.

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TABLES AND FIGURES

Table 1: Summary statistics of the dependent variables, per month.

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Waste recycling quota	1,776	0.257	0.156	0.028	0.709
Total waste per capita	1,776	39.619	13.413	16.835	161.13
Organic waste recycling quota	1,776	0.077	0.072	0	0.442
Multimaterial waste recycling quota	1,776	0.180	0.138	0.011	0.606

Table 2: Summary statistics of predictors in pre-treatment period.

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Quota of population with a high school diploma	37	0.385	0.046	0.314	0.499
Quota of population over 65	74	0.241	0.036	0.168	0.352
Quota of volunteers	37	0.107	0.057	0.033	0.360
Turnout, Referendum 2011	37	0.644	0.055	0.424	0.740
Quota of firms in the service industry	74	0.729	0.069	0.559	0.854
Personal income per capita	74	13,088	1,409	9,350	16,992
Hotels per capita	74	0.005	0.006	0.000	0.0335
Firms per capita	74	0.077	0.017	0.050	0.124
Density	74	267.4	262.8	8.076	1,375

Table 3: Control variables treated, synthetic control and donor pool (waste recycling quota).

	Treated	Synthetic	Donor pool
Personal income per capita	16,408	14,575	13,088
Quota of population over 65	0.278	0.249	0.241
Density	328	295	267
Quota of population with a high school diploma	0.499	0.451	0.385
Quota of volunteers	0.117	0.130	0.107
Hotels per capita	0.001	0.002	0.005
Quota of firms in the service industry	0.847	0.806	0.729
Firms per capita	0.088	0.090	0.077
Turnout, Referendum 2011	0.634	0.646	0.644
Waste recycling quota (January 2017)	0.242	0.219	0.167
Waste recycling quota (July 2016)	0.375	0.383	0.290
Waste recycling quota (January 2016)	0.384	0.421	0.309
Waste recycling quota (July 2015)	0.428	0.409	0.303

Table 4: Waste recycling quota: Real vs artificial Ferrara.

Month/Year	Lower bound	Upper bound	Treated	Month/Year	Lower bound	Upper bound	Treated
Pre-treatement period				Post-treatement period			
1/2015	0.390	0.431	0.399	7/2017	0.219	0.260	0.246
2/2015	0.413	0.454	0.439	*8/2017*	*0.200*	*0.241*	*0.273*
3/2015	0.413	0.454	0.447	*9/2017*	*0.219*	*0.261*	*0.318*
4/2015	0.441	0.482	0.454	*10/2017*	*0.224*	*0.265*	*0.362*
5/2015	0.425	0.466	0.455	*11/2017*	*0.217*	*0.259*	*0.465*
6/2015	0.391	0.432	0.443	*12/2017*	*0.209*	*0.250*	*0.556*
7/2015	0.389	0.430	0.428	*1/2018*	*0.219*	*0.260*	*0.642*
8/2015	0.366	0.408	0.416	*2/2018*	*0.224*	*0.265*	*0.648*
9/2015	0.410	0.451	0.450	*3/2018*	*0.233*	*0.274*	*0.653*
10/2015	0.397	0.438	0.440	*4/2018*	*0.236*	*0.277*	*0.662*
11/2015	0.443	0.484	0.463	*5/2018*	*0.232*	*0.274*	*0.661*
12/2015	0.410	0.451	0.443	*6/2018*	*0.242*	*0.284*	*0.671*
1/2016	0.401	0.442	0.384	*7/2018*	*0.234*	*0.275*	*0.696*
2/2016	0.402	0.444	0.418	*8/2018*	*0.238*	*0.280*	*0.709*
3/2016	0.404	0.446	0.450	*9/2018*	*0.254*	*0.295*	*0.692*
4/2016	0.419	0.460	0.422	*10/2018*	*0.248*	*0.289*	*0.677*
5/2016	0.413	0.455	0.420	*11/2018*	*0.243*	*0.284*	*0.671*
6/2016	0.402	0.444	0.434	*12/2018*	*0.235*	*0.277*	*0.658*
7/2016	0.362	0.404	0.375				
8/2016	0.365	0.407	0.362				
9/2016	0.393	0.434	0.393				
10/2016	0.406	0.448	0.397				
11/2016	0.412	0.453	0.440				
12/2016	0.415	0.457	0.387				
1/2017	0.198	0.240	0.242				
2/2017	0.202	0.243	0.250				
3/2017	0.204	0.246	0.238				
4/2017	0.201	0.242	0.225				
5/2017	0.204	0.245	0.240				
6/2017	0.233	0.274	0.244				

Table 5: Percentage waste recycling – percentage points differences with respect to the introduction PAYT system (July 2017) between treated and synthetic control.

Year/month	Treated	Synthetic	Treated-synthetic
17-Aug	0.027	-0.019	0.046
17-Sep	0.072	0.000	0.072
17-Oct	0.116	0.005	0.111
17-Nov	0.220	-0.002	0.221
17-Dec	0.310	-0.010	0.320
18-Jan	0.397	0.000	0.397
18-Feb	0.402	0.005	0.397
18-Mar	0.408	0.014	0.394
18-Apr	0.416	0.017	0.399
18-May	0.415	0.013	0.402
18-Jun	0.426	0.023	0.403
18-Jul	0.450	0.015	0.435
18-Aug	0.463	0.019	0.444
18-Sep	0.446	0.035	0.411
18-Oct	0.431	0.029	0.402
18-Nov	0.426	0.024	0.402
18-Dec	0.412	0.016	0.396

Table 6: Control variables treated, synthetic control and donor pool (total waste per capita).

	Treated	Synthetic	Donor pool
Personal income per capita	16,408	14,636	13,088
Quota of population over 65	0.278	0.247	0.241
Density	328	329	267
Quota of population with a high school diploma	0.499	0.439	0.385
Quota of volunteers	0.117	0.123	0.107
Hotels per capita	0.001	0.003	0.005
Quota of firms in the service industry	0.847	0.780	0.729
Firms per capita	0.088	0.083	0.077
Turnout, Referendum 2011	0.634	0.640	0.644
Waste recycling quota (January 2017)	30.532	29.151	29.068
Waste recycling quota (July 2016)	39.420	40.306	47.315
Waste recycling quota (January 2016)	38.063	39.115	37.285
Waste recycling quota (July 2015)	44.911	44.594	48.822

Table 7: Total per capita waste – percentage points differences with respect to the introduction PAYT system (July 2017) between treated and synthetic control.

Year/month	Treated	Synthetic	Treated-synthetic
17-Aug	-0.088	-0.027	-0.062
17-Sep	-0.019	-0.019	0.000
17-Oct	-0.059	-0.001	-0.058
17-Nov	-0.171	-0.040	-0.131
17-Dec	-0.254	-0.064	-0.190
18-Jan	-0.282	-0.045	-0.237
18-Feb	-0.321	-0.175	-0.146
18-Mar	-0.233	-0.033	-0.200
18-Apr	-0.317	-0.029	-0.288
18-May	-0.255	0.046	-0.301
18-Jun	-0.296	0.018	-0.314
18-Jul	-0.309	0.014	-0.323
18-Aug	-0.325	-0.008	-0.316
18-Sep	-0.336	-0.039	-0.297
18-Oct	-0.237	0.065	-0.302
18-Nov	-0.233	0.001	-0.235
18-Dec	-0.231	-0.035	-0.196

Table 8: Control variables treated, synthetic control and donor pool (organic waste recycling).

	Treated	Synthetic	Donor pool
Personal income per capita	16,408	14,418	13,088
Quota of population over 65	0.278	0.267	0.241
Density	328	242	267
Quota of population with a high school diploma	0.499	0.428	0.385
Organic waste recycling quota (January 2017)	0.124	0.124	0.079
Quota of volunteers	0.117	0.140	0.107
Organic waste recycling quota (January 2016)	0.090	0.090	0.051
Hotels per capita	0.001	0.004	0.005
Quota of firms in the service industry	0.847	0.808	0.729
Organic waste recycling quota (July 2015)	0.086	0.099	0.070
Firms per capita	0.088	0.083	0.077
Organic waste recycling quota (July 2016)	0.099	0.100	0.066
Turnout, Referendum 2011	0.634	0.635	0.644

Table 9: Control variables treated, synthetic control and donor pool (Multimaterial waste recycling).

	Treated	Synthetic	Donor pool
Personal income per capita	16,408	14,060	13,088
Quota of population over 65	0.278	0.243	0.241
Density	328	329	267
Quota of population with a high school diploma	0.499	0.429	0.385
Multimaterial waste recycling quota (January 2017)	0.294	0.296	0.258
Quota of volunteers	0.117	0.118	0.107
Multimaterial waste recycling quota (January 2016)	0.118	0.118	0.087
Hotels per capita	0.001	0.003	0.005
Quota of firms in the service industry	0.847	0.761	0.729
Multimaterial waste recycling quota (July 2015)	0.342	0.341	0.233
Firms per capita	0.088	0.088	0.077
Multimaterial waste recycling quota (July 2016)	0.276	0.277	0.224
Turnout, Referendum 2011	0.634	0.636	0.644

Table 10: Organic and multimaterial percentage waste recycling – percentage points differences with respect to the introduction of PAYT system (July 2017) between treated and synthetic control.

Year/month	Treated	Synthetic	Treated-synthetic	Treated	Synthetic	Treated-synthetic
	Organic waste			Multimaterial waste		
17-Aug	0.013	-0.015	0.028	0.014	-0.009	0.023
17-sep	0.015	-0.015	0.030	0.058	0.011	0.047
17-oct	0.052	-0.003	0.055	0.064	0.011	0.053
17-nov	0.114	-0.008	0.122	0.106	0.025	0.081
17-Dec	0.180	-0.015	0.195	0.130	0.011	0.119
18-Jan	0.247	-0.006	0.253	0.149	0.032	0.118
18-feb	0.249	-0.008	0.257	0.153	0.034	0.120
18-mar	0.237	-0.014	0.251	0.171	0.023	0.147
18-Apr	0.257	-0.001	0.258	0.160	0.022	0.138
18-may	0.257	-0.006	0.262	0.158	0.018	0.140
18-jun	0.262	0.006	0.256	0.164	0.024	0.140
18-jul	0.295	0.012	0.283	0.155	0.014	0.141
18-Aug	0.309	0.024	0.285	0.155	0.002	0.153
18-sep	0.263	0.014	0.249	0.183	0.027	0.156
18-oct	0.252	0.005	0.247	0.179	0.016	0.163
18-nov	0.256	0.007	0.249	0.170	0.020	0.150
18-Dec	0.253	-0.006	0.259	0.160	0.020	0.139

Table 11: Municipal-placebo experiments for waste recycling quota.

Municipality	Ratio	RMSPE pre-treatment	RMSPE post-treatment
Ferrara	17.696	0.020	0.362
Faenza	8.152	0.015	0.123
Castel Bolognese	3.317	0.028	0.094
Bagnacavallo	2.743	0.016	0.043
Imola	2.463	0.054	0.133
Gatteo	1.915	0.046	0.088
Conselice	1.913	0.032	0.061
Brisighella	1.757	0.033	0.059
Cesena	1.714	0.048	0.083
Santa Sofia	1.703	0.040	0.068
Cotignola	1.661	0.013	0.021
Bagno di Romagna	1.649	0.028	0.047
Ravenna	1.587	0.032	0.051
Cesenatico	1.514	0.017	0.025
Alfonsine	1.502	0.018	0.027
Russi	1.499	0.036	0.053
Savignano sul Rubicone	1.440	0.024	0.034
Bagnara di Romagna	1.338	0.042	0.056
Lugo	1.335	0.018	0.024
Verghereto	1.283	0.031	0.039
Gambettola	1.134	0.051	0.057
Solarolo	0.991	0.023	0.023
Fusignano	0.981	0.034	0.033
Longiano	0.952	0.030	0.029
Sogliano al Rubicone	0.948	0.031	0.030
Massa Lombarda	0.922	0.032	0.029
San Mauro Pascoli	0.912	0.042	0.038
Sarsina	0.883	0.019	0.017
Roncofreddo	0.824	0.021	0.017
Mercato Saraceno	0.750	0.023	0.017
Sant'Agata sul Santerno	0.670	0.056	0.038
Casola Valsenio	0.639	0.036	0.023
Premilcuore	0.614	0.068	0.042
Riolo Terme	0.537	0.041	0.022
Borghi	0.437	0.036	0.016
Montiano	0.309	0.053	0.016
Cervia	0.252	0.079	0.020

Table 12: Fake month/year implementation for waste recycling quota.

Fake month/year	Ratio	RMSPE pre-treatment	RMSPE post-treatment
1/2016	0.135	0.260	0.035
2/2016	0.144	0.275	0.040
3/2016	0.152	0.259	0.039
4/2016	0.146	0.263	0.038
5/2016	0.159	0.235	0.037
6/2016	0.126	0.266	0.034
7/2016	0.112	0.256	0.029
8/2016	0.120	0.253	0.030
9/2016	0.126	0.259	0.033
10/2016	0.121	0.253	0.031
11/2016	0.131	0.250	0.033
12/2016	0.087	0.232	0.020
1/2017	0.128	0.247	0.032
2/2017	0.083	0.239	0.020
3/2017	0.044	0.218	0.010
4/2017	0.055	0.226	0.012
5/2017	0.032	0.224	0.007
Main specification	17.696	0.020	0.362

Figure 1: Municipal waste in 25 OECD countries, 2000-2017: kg. per capita.

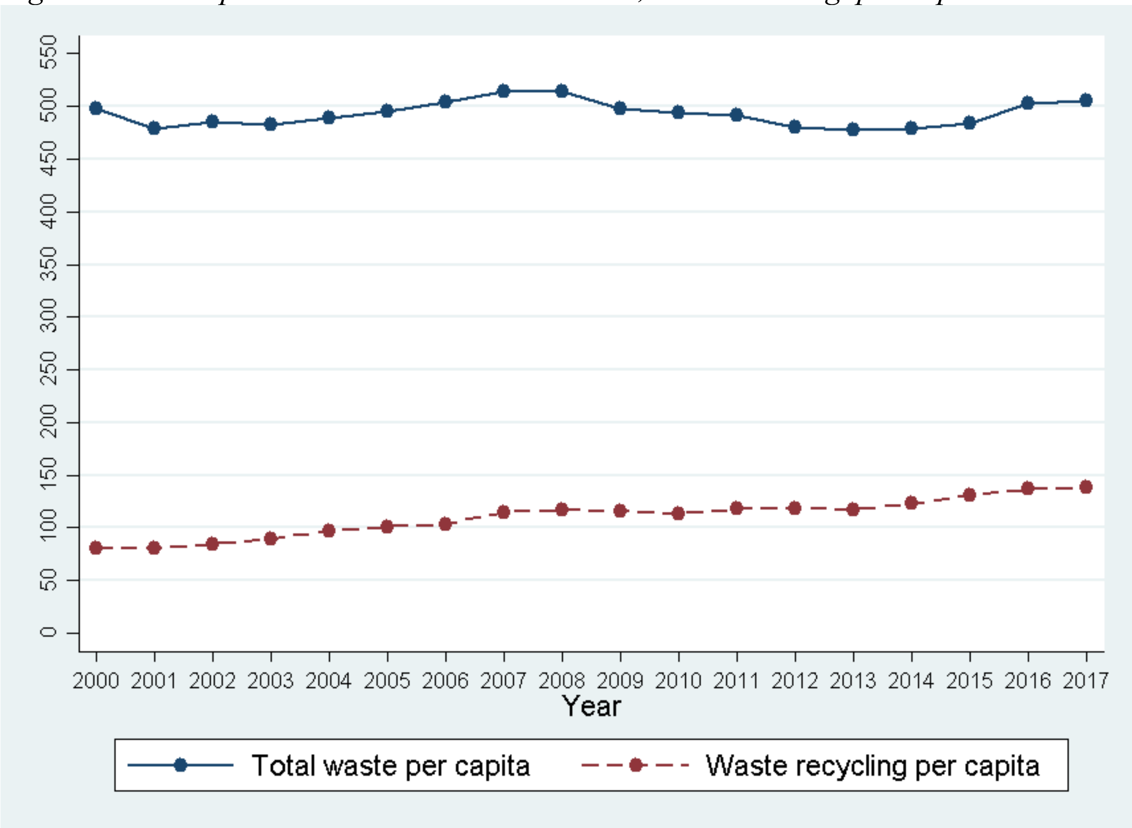


Figure 2: Ferrara vs synthetic control, waste recycling quota.

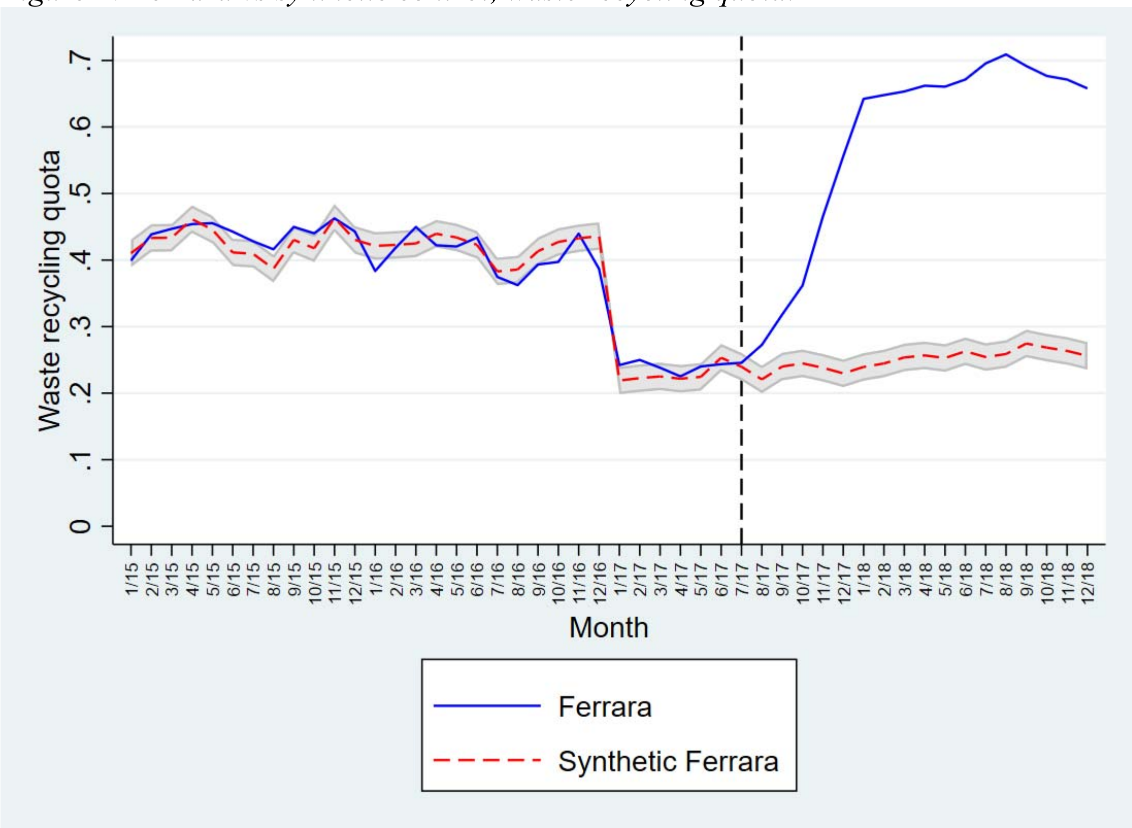


Figure 3: Ferrara vs synthetic control, total waste per capita.

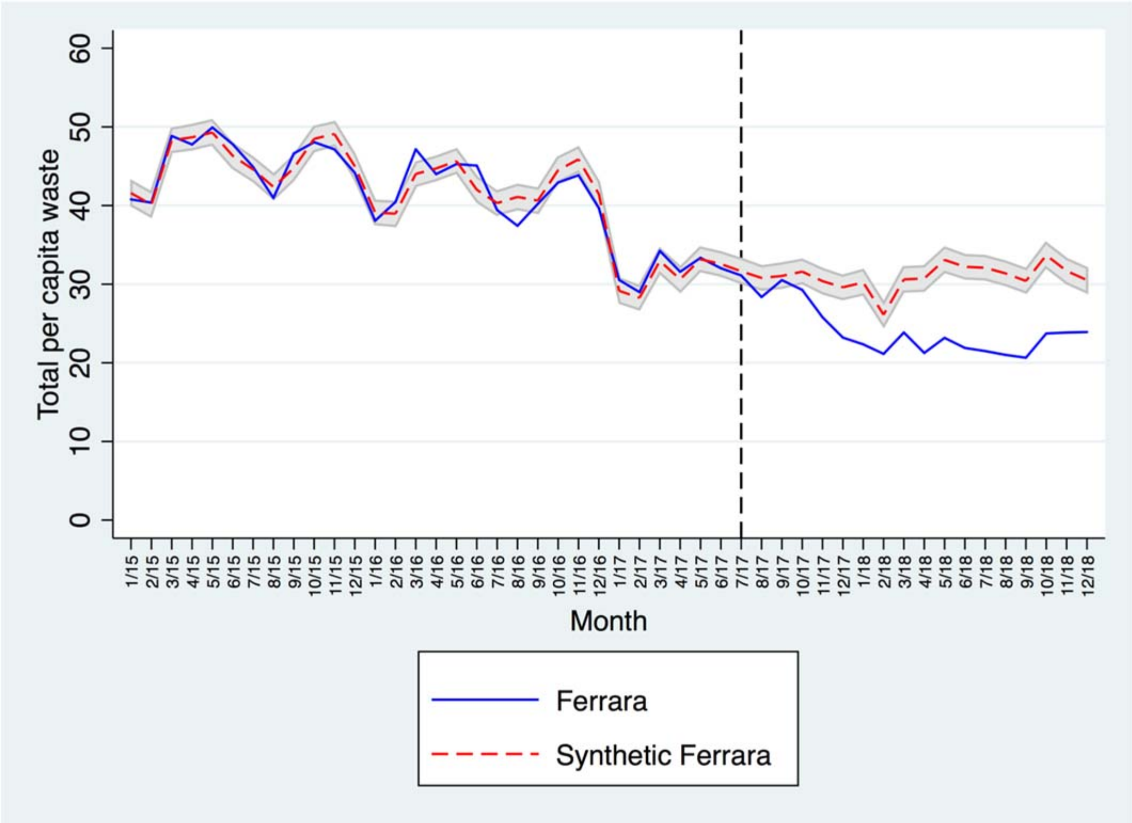


Figure 4: Ferrara vs synthetic control, percentage of organic waste recycling on total waste.

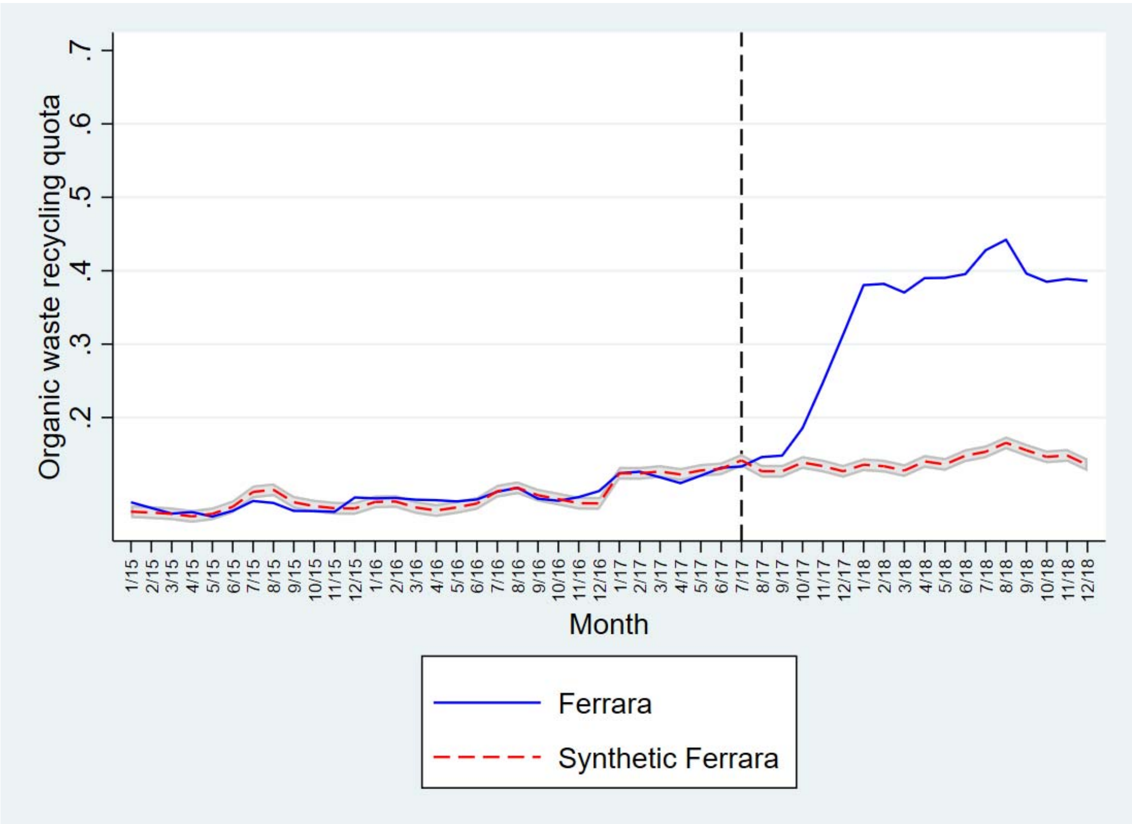


Figure 5: Multimaterial waste recycling. Ferrara vs synthetic control.

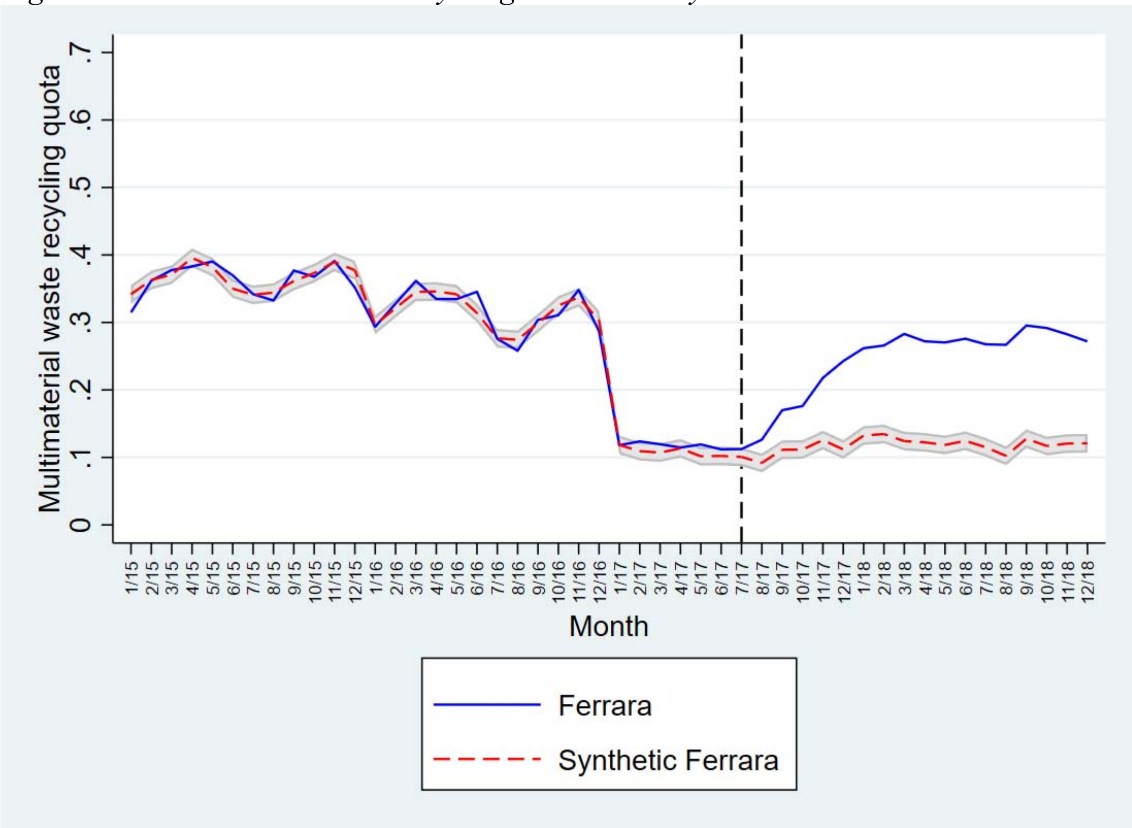


Figure 6: Ferrara vs synthetic control, excluding from the donor group all municipalities with ratio greater than 1.

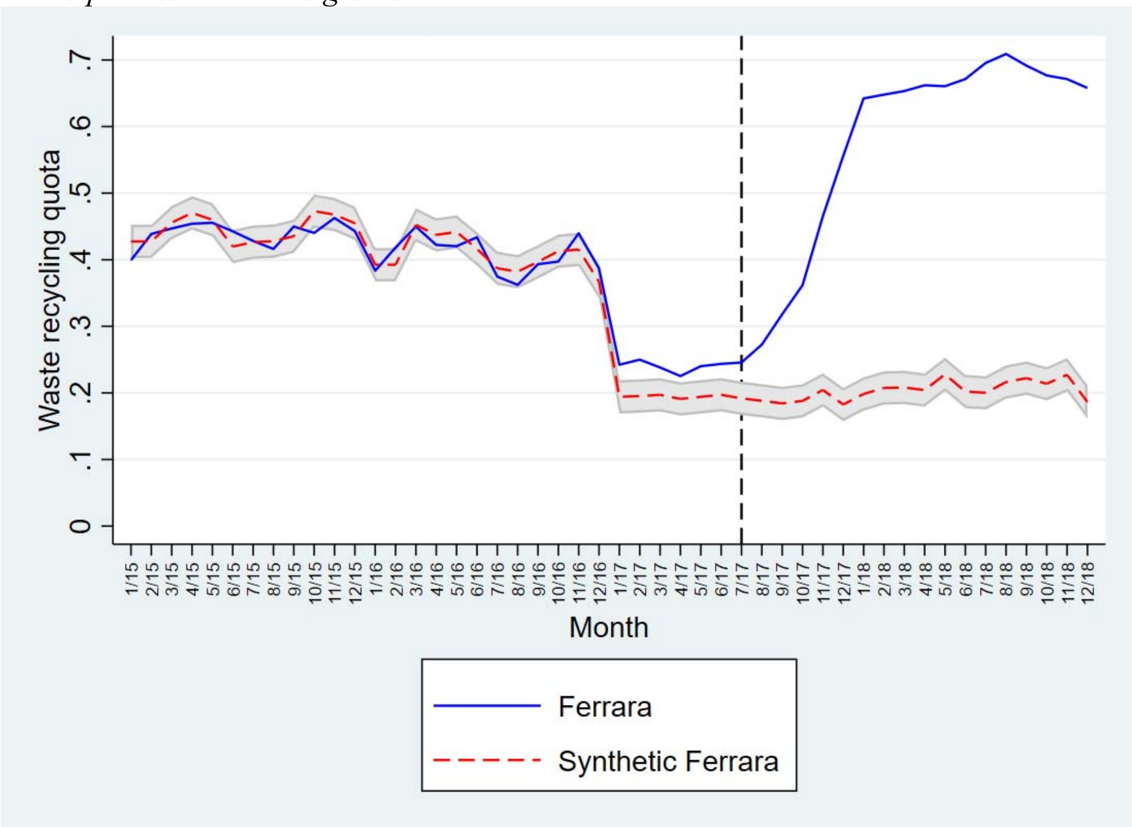


Figure 7: Difference between real and synthetic Ferrara vs spatial placebos. Waste recycling quota.

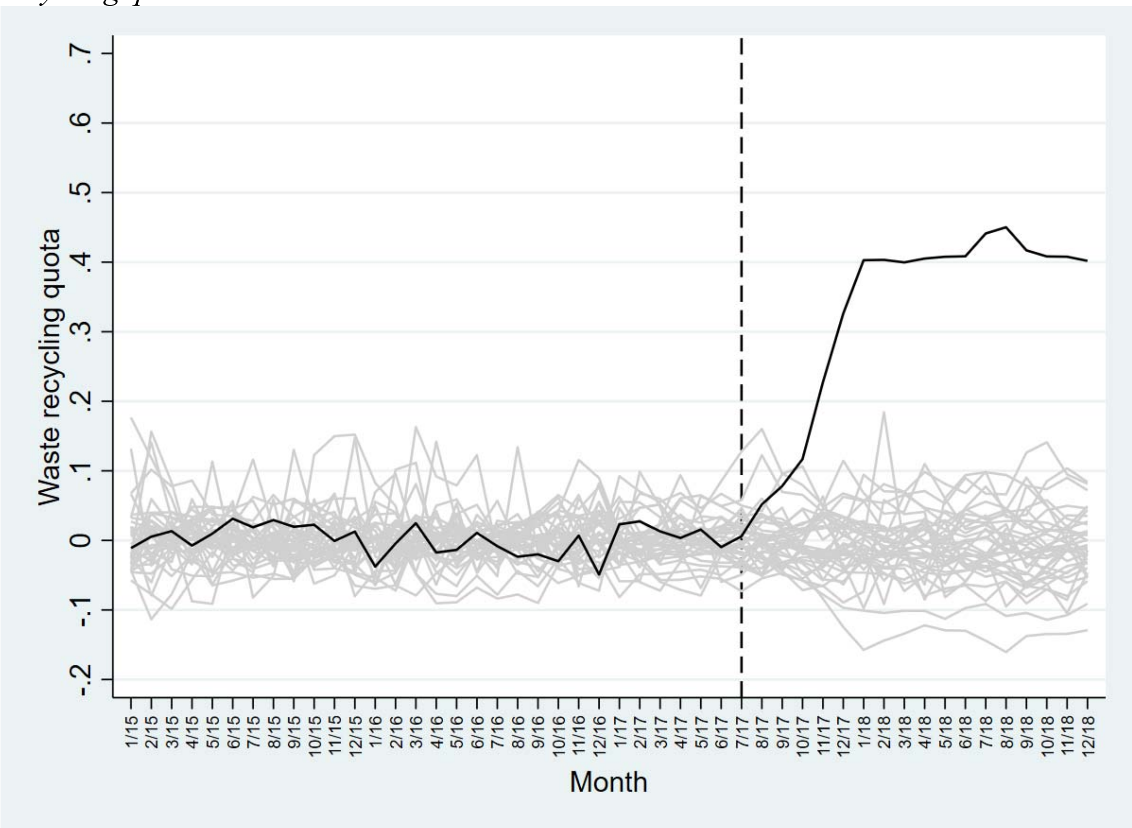
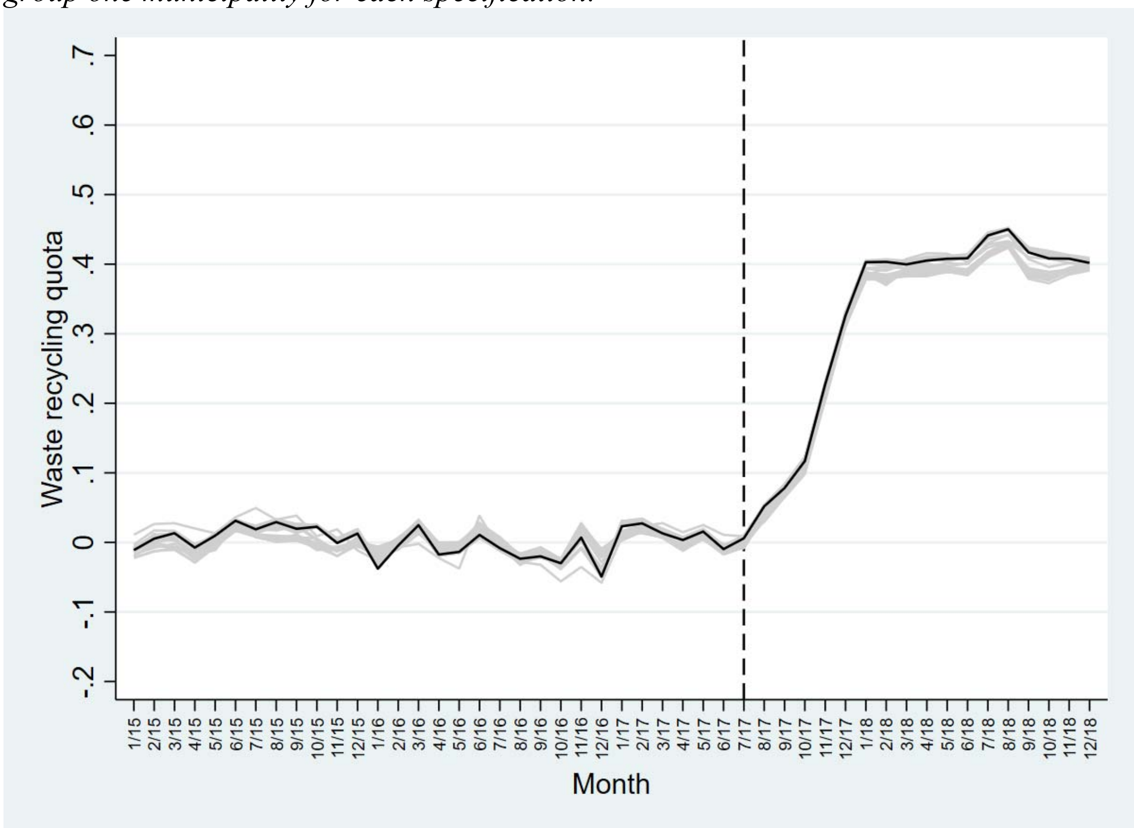


Figure 8: Difference between real and synthetic Ferrara, excluding from the donor group one municipality for each specification.



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Appendix

A - Description of the tariff including the PAYT system

The computation of the waste tariff with the PAYT is given by the following:

$$Waste\ tariff\ = ff\ +\ bvf\ +\ avf - A \qquad (1)$$

where (*ff*) is a fixed fee, (*bvf*) is a basic variable fee, (*avf*) is an additional variable fee and (A) is the allowance linked to socio-economic conditions of the user. The fixed fee (*ff*) covers fixed costs that are independent of the quantities of waste collected. In particular the fixed costs are allocated to each user according to the area in square meters of the house and the number of members in the family (column 2 – Table 1).

The basic variable fee (*bvf*) is also computed with reference to the number of family members and the area in square meters of the house, assuming a minimum supply of liters of waste by the family (column 3 – Table 1). The *bvf* is equal to the product of the minimum in col. 3 Table 1 times the price per liter (0.055 €).

The additional variable fee (*avf*) is the part of the waste tariff linked to the PAYT system. This fee is related to the quantity of unsorted waste, which exceed the threshold after which the fee is activated (column 3 – Table 1). Therefore the amount for the *avf* is equal to the product between the liters of unsorted waste minus the minimum, and the unit cost of the service (in 2019 it was 0.055 € / liter).

[INSERT TABLE A1 AROUND HERE]

There are some allowances to the waste rate (A): there is only one affecting the incentive to produce waste recycling which is linked to the use of specialized waste collection centers. For each deposit of waste for recycling at a collection center, users can deduct from the waste tariff a certain fee based on the type and weight of the waste deposited (Table 2). There are also several other allowances for domestic users[12].

[INSERT TABLE A2 AROUND HERE]

[12] For example an allowance if there is a baby in the family unit, or if the family usually uses medical-health devices under medical prescription (Ferrara City Council Resolution n.6/2014).

Table A1: Components of the waste tariff with the PAYT system in Ferrara, domestic users – year 2019.

Number Household members (1)	*Fixed fee (€/square meter)* (2)	*Minimum annual litres* (3)
1	1.021	1,080
2	1.357	1,380
3	1.555	1,560
4	1.647	1,740
5	1.906	1,920
6 or more	2.058	2,100

Source: Municipality of Ferrara (2019).

Table A2: Incentive deduction for deposits to a waste collection center.

Type of waste	*Unit deduction (€/kg)*
Batteries and accumulators	0,20
Medicines	0,30
Edible oils	0,20
Paper and cardboard, plastic, wood, metal, glass, textile and mixed packaging	0,05
Electrical and electronic equipment	0,05
Bulky waste	0,05
Mixed waste from small construction and demolition activities	0,01

Source: Municipality of Ferrara (2019).

B - The synthetic control method

Following the approach of Abadie Diamond and Hainmueller (2015), we take a sample of K+1 units, indexed by k, where k =1 is the "case of interest" or "treated unit", and k = 2... K+1 are the "potential comparisons," which make up the donor pool. The units are observed at the same time t periods, t = 1, ... T with a given pre- and a post-intervention period. The synthetic control is the weighted average of the units in the donor pool; so, it is a $(K \times 1)$ vector of weights $W = (w_2. .... W_{K+1})$, with $0 \leq w_k \leq 1$ for $k = 2, ... K$ s.t. $w_2 + ... + w_{J+1} = 1$.

We let $X_1 = (s \times 1)$ be the vector of the values for the pre-intervention characteristics of the treated unit, and $X_0 = (s \times K)$ is the matrix collecting the values of the same variable for all the other units in the donor pool. These variables are chosen so that they are good predictors of the outcome variable within vector X_1 and pre-intervention values of the outcome variable may themselves be included. A synthetic control, W, is selected such that the size of the difference between the pre-intervention characteristics of the treated unit and the units of the donor pool is minimized; in particular, V and W are simultaneously chosen such that they minimize the weighted mean square error $(X_1 - X_0W)' V(X_1 - X_0W)$, where V is a diagonal of predictor weights, which reflects the relative importance assigned to the predictor variables when the discrepancy between X_1 and X_0W is measured. We choose the predictor weights V, as Abadie, Diamond and Hainmueller (2010) do, by minimizing $(Z_1 - Z_0W(V))' (Z_1 - Z_0W(V))$, where Z_1 is a vector and Z_0 is a matrix of the dependent variable before the treatment for the treated and for the donor group, respectively.

We then let $Y_1 = (T_1 \times 1)$ be the vector of the post-intervention values of the outcome for the treated unit and $Y_0 = (T_1 \times K)$ be the matrix collecting the values of the same variables for all the units in the donor pool. The synthetic control estimator of the effect of the treatment is given by $(Y_1 - Y_0W)$. Since we construct a synthetic control unit with similar behaviors to the treated unit in the pre-intervention period, a discrepancy in the outcome variable after the intervention is interpreted as the true effect of the intervention itself.

C - Municipalities in the “donor pool”

Municipality
Ferrara
Faenza
Castel Bolognese
Bagnacavallo
Imola
Gatteo
Conselice
Brisighella
Cesena
Santa Sofia
Cotignola
Bagno di Romagna
Ravenna
Cesenatico
Alfonsine
Russi
Savignano sul Rubicone
Bagnara di Romagna
Lugo
Verghereto
Gambettola
Solarolo
Fusignano
Longiano
Sogliano al Rubicone
Massa Lombarda
San Mauro Pascoli
Sarsina
Roncofreddo
Mercato Saraceno
Sant'Agata sul Santerno
Casola Valsenio
Premilcuore
Riolo Terme
Borghi
Montiano
Cervia