Does It Take More Than One Village?

The Effect of Inter-Municipal Cooperation on Waste Separation

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Abstract

Municipalities increasingly cooperate with one another to improve their public services. In this study, we estimate the causal effect of Inter-Municipal Cooperation (IMC) on the environmental performance of waste collection in Catalonia. Using a difference-in-differences framework, we find that municipalities moving into IMC decrease non-separated waste per capita and increase the share of waste separation. However, when taking into account potential selection into treatment, a causal effect is present only in a sub-period after a strong hike in the landfill tax, and particularly for municipalities switching after this tax hike. This points to IMC's potential to use technical capability and economies of scale for a more pronounced and rapid reaction, enhancing the effectiveness of higher-level policy. In contrast, absent the landfill tax, IMC seems to have offered limited improvement in environmental performance, suggesting at most a secondary role for internalization of local environmental spillovers..

JEL Classification: H41, H77, Q53

Keywords: Inter-Municipal Cooperation, Waste Management, Recycling, Selection into Treatment, Difference-in-Differences

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Acknowledgements: Funding has been provided by the Ministry of Science and Innovation (Government of Spain), Grant #PID2022-138866OB-I00 and ERDF/EU; and Institut d'Estudis per l'Autogovern (IEA-Generalitat de Catalunya), Grant # PRE150/22/000005. We thank Carles Pi i Sunyer Foundation for providing data for IMC in local services. Comments and suggestions by Joan Ramon Borrell, Julia de Frutos, Antonio di Paolo, Osman Hakan, Marianna Magagnoli, Jordi Teixidó, Serge Garcia, Mehdi Guelmamen, Emilien Macault, Alexandre Mayol, Sarah Van Driessche, Roberto Iacono, Rino Heim, Paul Meiners and Benjamin Engst as well as the participants of the Annual Conference of AECR, and seminars at Université de Lorraine, NTNU Trondheim and CREDA-UPC-IRTA were very useful.

1 Introduction

The amount of waste generated globally is forecast to increase from 2.24 billion tons in 2020 to 3.88 billion tons in 2050, an increase by about 70%, and residential waste is likely to increase as urbanization continues (Kaza, Shrikanth, and Chaudhary 2021). Both the volume and growth of waste pose many challenges from an environmental point of view: Reducing material use, greenhouse gas emissions and limiting local pollution are just the most pertinent ones. In order to achieve a more circular economy, the European Union has singled out recycling as one of the most important levers (European Commission 2020). In particular, it has set its member states a target to increase recycling and reuse rates of municipal waste to 55% by 2025 and to 60% by 2030 (European Environment Agency 2023). In order to recycle a wide range of waste components, these have to be separated either at source (i.e. by the final consumer) or post-source (at a sorting plant).

While national and supra-national political institutions often promote or mandate improvements to waste management, in most countries it is municipalities which are responsible for managing the service and introducing related policies. In contrast, many of the environmental effects of sound waste management are regional or even global in nature. Thus, there may be incentives for local policy makers to underinvest in dealing with the related environmental challenges.

Some authors have suggested that Inter-Municipal Cooperation (IMC) - often termed shared delivery in the US - may be one key to resolve this issue. With IMC, two or more local governments provide one or several services jointly within their jurisdictions (Hulst and Van Montfort 2012). Interlocal contracts are the most frequent form of implementing IMC in the US, while institutionalized IMC (i.e., with joint governance, or with delegation) is most frequent in Europe (Bel and Warner 2015). IMC moves the emphasis within public services from competition towards collaboration, and potentially helps to address problems of spillovers between local jurisdictions (Agranoff and McGuire 2003). By extending the area where the service is provided, it becomes less fragmented and a larger share of the environmental effects may occur within the larger service area. This may counteract the effect of jurisdictional fragmentation. The aim of this paper is to evaluate the merit of this hypothesis by estimating the causal effect of IMC on the environmental performance of waste collection in Catalonia. Our paper connects these findings to a wider field of investigation concerned with the environmental performance of governance institutions: Most importantly for our case, a number of studies find that more jurisdictional fragmentation leads to more pollution, in line with the effects accruing outside of the jurisdictional area for which policy makers are responsible (e.g. Hatfield and Kosec 2019; Burgess et al. 2012; Lipscomb and Mobarak 2017).

The previous empirical literature on IMC in waste management has mainly focused on its effects on service delivery costs (Bel and Sebő 2021). But the emphasis on the financial consequences of engaging in IMC is also evident in work on other services (e.g. Ferraresi, Migali, and Rizzo 2018; Elston, Bel, and Wang 2023; Notsu 2024). Apart from delivery costs, effects on service quality have sparked a lot of interest (e.g. Holum and Jakobsen 2016; Klok et al. 2018; Arntsen, Torjesen, and Karlsen 2021; Blåka 2017; Blåka, Jacobsen, and Morken 2023; Elston, Bel, and Wang 2023, 2024; Sandberg 2024; Tricaud 2024).

Besides the study by Bel and Elston (2024), the environmental dimension of IMC in waste management has not been investigated by means of quantitative analysis. This reflects that empirical research on the environmental effects of IMC is generally scarce, although rapidly emerging. A case study by Perrin and Bouisset (2022) investigates IMC in energy production, and Villalba Ferreira et al. (2022) in waste management. More quantitative research has investigated the relationship between metropolitan governance and CO_2 emissions in public transport (Osei Kwadwo and Skripka 2022). Furthermore, Youm and Feiock (2019) have analyzed the role of state and federal rules and policies for cooperation in climate action. However, none of these studies have attempted to pin down the causal effect of IMC in environmental policy.

Our work is also related to the literature evaluating the effect of other factors on environmental performance in waste management. On one hand, these studies document positive effects of collection techniques such as Unit-Based Pricing / Pay as You Throw (Dijkgraaf and Gradus 2015; Bel and Gradus 2016) and Door-to-Door (Saldivia Gonzatti, Jannes, and Barreal 2022). On the other hand, authors have also investigated the effect of green political platforms (Cerqua, Fiorino, and Galli 2024), and higher-level policies such as landfill taxation (Jofre-Monseny and Sorribas-Navarro 2024).

We contribute to the literature by offering, to the best of our knowledge, the first causal evidence on the effect of inter-municipal cooperation in waste collection on the environmental performance of the service. Namely, we use difference-in-difference designs and account for selection into cooperation by relying on parallel trends conditional on observable drivers of such selection. We use a panel over a 14 years period (2009-2022), covering essentially all municipalities above 500 inhabitants in Catalonia. We focus on the effect of IMC on the separation rate and the weight per capita of non-sorted waste.

We find that moving into IMC is associated with increases of waste selection and decreases of non-sorted waste. The effect is driven by a sub-period of the sample when Catalonia increased its landfill tax. Once accounting for mechanisms of selection into treatment, we find that the causal effect of IMC is only present during this period when the landfill tax had already started to increase strongly, and particularly for those municipalities moving into IMC after the tax hike.

We interpret our results as evidence that IMC may not in and of itself succeed at internalizing enough of the spillovers created by waste management, because a large part of these spillovers may accrue outside even a larger inter-municipal grouping (the county, in our case). Instead of internalizing very local spillovers, IMC seems to have allowed municipalities a more pronounced reaction to the landfill tax, increasing the effectiveness of this regional policy. Thus, not so much considerations about spillovers, but more general advantages in governance or technical capacity under IMC may have proven crucial for IMCs environmental benefits.

The rest of this article is structured as follows. In Section 2, we discuss the institutional background in which IMC takes place in Catalonia. We then present the data and descriptive statistics in Section 3. Next, we describe our empirical strategy (Section 4) and guide through the results (Section 5) and discuss how the increase of the landfill tax may have modified IMC's effect. We then provide results with a relaxed parallel trends assumption in Section 6. In Section 7, we conclude the article with a discussion of our results and their policy relevance, specifically also in relation to other policy measures.

2 Institutional Background

Local administration in Catalonia is organized into 947 municipalities at the basic level, with the average municipality inhabited by about 8.300 people. Thus, municipalities are on average similar in size to the US, substantially larger than in France, but much smaller than in Japan, the UK, Mexico or Scandinavia. In Catalonia (and Aragon), the counties have been recognized by regional laws as key supra-municipal level of local government. There are 42 counties,[1] which play a central role in the organization of inter-municipal cooperation. Each municipality belongs to a county.

While waste treatment is predominantly managed by counties or even a group of counties, waste collection is the responsibility of municipalities. Since 2009, they are obliged to provide a collection system which includes selective collection. Thus, the weight of non-separated and total waste and the share of separation at the stage of collection are a function of local citizen behavior, which is induced by local policies.[2] Municipalities can either provide waste collection independently or join in a type of IMC *for this specific service*. There are three main ways to provide the service:

1. **The own municipality** provides waste collection without inter-municipal co-operation
2. Municipalities can **delegate** the service **to the county**, if the council has decided to offer waste collection; service provision is then governed by the county council exclusively
3. The municipality can become part of a **mancommunity**, which is then jointly governed by the member municipalities

For the purpose of the study here, we consider options 2) and 3) as engaging in IMC, and 1) as standalone provision. Particularly delegation to the county council is very common in services of certain characteristics, among them solid waste collection. Delegation of the service to the county council – and, in general, joining an IMC- is strictly voluntary, as is withdrawal; this is similar to most countries, but different from mandatory and irreversible cooperation like that of France (see

[1] Plus the Vall d'Aran, a singular jurisdiction that can be treated as another county for our research purposes

[2] These can include far-reaching policies such as Door-to-Door or unit-based pricing (which is very rare in Catalonia), but also adjustments to collection frequency or container availability for the different fractions, separation promotion campaigns etc.

Tricaud 2024). Interlocal contracts are extremely rare (Bel and Elston 2024). The Catalonian Waste Agency (ARC) regulates waste management in Catalonia, according to directives by the European Union. Thus, all municipalities are subordinate to the same legislation.

The counties as the key entity for IMC are governed according to the following principles: A county council is composed according to the results of the municipal elections of the municipalities that belong to the county. Each political party appoints its representatives to the council. The county councilors then elect a president, and the county councilors for specific government areas are appointed by this president.

3 Data

This article uses two main data sources for the two main variables.

Inter-municipal co-operation in waste collection. This variable is obtained from a bi-annual survey by the "Carles Pi i Sunyer foundation for studies of autonomous community and local government". The survey was conducted in 2009, 2011, 2013, 2014, 2016, 2018, 2020 and 2022, and data were collected through personal interviews with high-level government officials in the municipalities. It was administered to all municipalities with at least 500 inhabitants [3] in the first four survey periods, the number of included municipalities was then steadily increased, and the survey was administered to all municipalities in 2022. To have a balanced panel, we focus on those municipalities which had more than 500 inhabitants in at least one period up to 2014, and were included in at least one survey as a consequence. Thus, the initial sample includes 613 municipalities, at least 99% of all municipalities above 500 inhabitants in a given year.

Household waste and separation rates. Total and residual household waste and waste separation rates are available in a data set for all municipalities in Catalonia, ranging from 2000 to 2022. The data is provided by Agència de Residus de Catalunya (2023). According to Briguglio (2016), most studies have used the share of separated materials for similar investigations, but since this may be misleading if a measure also decreases total waste quantity, we also use residual waste. Using the

[3] except for Barcelona

included population data for each municipality, we therefore calculate total and residual waste per capita at the level of a municipality. Since both variables are very skewed, we use the natural logarithms.

From the sample of 613 municipalities, we remove those which were always engaging in IMC (always treated; 248), and those who de-cooperate or switched multiple times (62). We also remove those who are likely switchers or stayers but contain missing values which we could not complete through publicly available information (31). We end up with a sample of 272 units, of which 77 switch into treatment and 195 units stay untreated throughout the 8 sample periods. Our sample thus contains 2176 survey wave × municipality combinations.

Table 1 below displays the balance of important pre-treatment covariates for treated and control units at the beginning of the sample period (in 2009). Treated and control municipalities are relatively similar regarding the outcomes (separation, natural logarithm of refuse and total waste). To put the figures of around 35 percent of separation in 2009 into perspective: In 2023, the average separation rate in Catalonia was 46.7%, which resulted in a recycling rate about 6-7 percentage points lower (Agència de Residus de Catalunya 2024). Thus, the region's separation rates still fall about 15 percentage points short of a level allowing to meet the 2025 EU recycling target of 50%; the same also holds for a target of maximum 10% of waste being sent to landfill (Agència de Residus de Catalunya 2024).

In contrast to the outcomes, there are significant differences in other important dimensions. Treated municipalities are on average much smaller[4] and politically slightly less to the left than the control group. Their inhabitants are slightly older and less highly educated. They are also less exposed to tourism, although this difference is not statistically significant.

[4] This also results in a lower population density, as their average surface area is comparable to control units.

Table 1: Means (standard deviations) of the main covariates and outcome variables

	Control group	Treatment group	F-test
Population	20819.821	4822.078	F=13.49***
	(37944.64)	(6740.92)	
C-left parties	0.571	0.543	F=9.815***
	(0.07)	(0.059)	
Pop. shr. 65 and older	0.153	0.169	F=6.787***
	(0.044)	(0.048)	
Pop. shr. 14 and younger	0.162	0.156	F=2.63
	(0.027)	(0.025)	
Tertiary education	32.372	30.552	F=2.993*
	(8.21)	(6.716)	
Tourism index	1350.431	764.961	F=1.328
	(4120.099)	(2702.988)	
selection	35.295	34.494	F=0.136
	(15.769)	(17.137)	
ln(residual/cap)	5.889	5.846	F=0.409
	(0.5)	(0.514)	
ln(waste/cap)	6.367	6.31	F=1.62
	(0.334)	(0.316)	
nobs.	195	77	

Significance levels: * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Particularly the differences in population size are not surprising, if we take into account the geographical distribution of the two groups. According to Figure 1, control municipalities are much more concentrated along the coast of Catalonia (along the lower right border), and there is also a clustering in the metropolitan area of Barcelona (coloured cluster in the centre of the coast).

Treatment municipalities are more spread out, but they are mostly situated more inland. Since the population in Spain and in Catalonia is quite concentrated along the coast, these geographical factors are reflected in differences in population size.

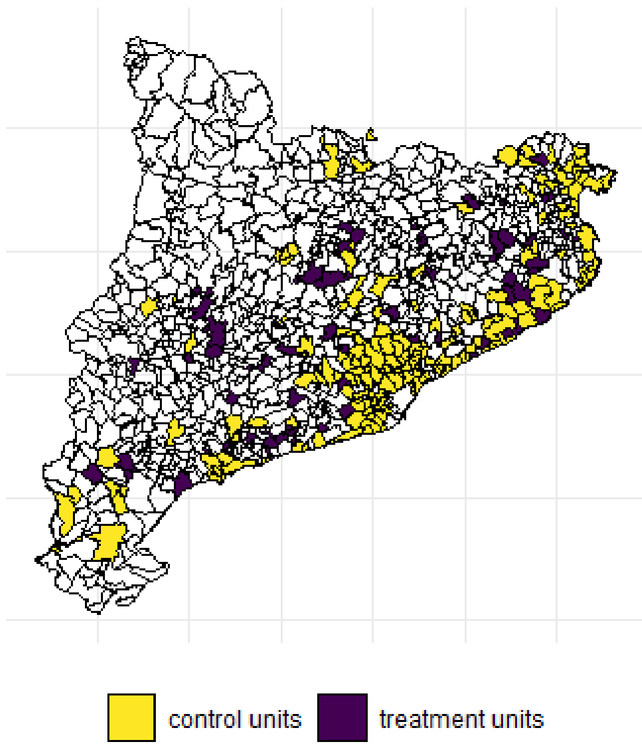

Figure 1: Geographical distribution of treatment and control units

4 Estimation Equation and Identification Strategy

Our empirical setting is in the context of panel data with staggered adoption of IMC over time. The standard empirical strategy in this setting is to use a two-way fixed-effect model of the following type:

$$Y_{it} = \tau IMC_{it} + \alpha_i + \gamma_t + \epsilon_{it}$$

where Y_{it} refers to the outcomes for each individual i survey wave t, averaged over the follow-up periods before the next survey wave. τ is our parameter of interest, which measures the effect of IMC on the outcomes. and α_i and γ_t capture municipality and time fixed-effects, respectively.

However, the TWFE estimator τ from the equation above is only equivalent to a Difference-in-Difference estimator with just *one* treated and an untreated group under strong conditions: The effects need to be stable or at least equally distributed across groups and over time (Gardner 2022), or the treatment actually has to occur at the same time for all units (De Chaisemartin and D'Haultfœuille 2020). The first is extremely unlikely, and the second ruled out by design in our staggered adoption setting. In these cases, τ is a weighted average of all two-group, two periods average treatment effects, but the weights by which the TWFE estimator aggregates these effects to τ are somewhat arbitrary (De Chaisemartin and D'Haultfœuille 2020). Since the TWFE estimator also makes "forbidden" comparisons with always treated units, these weights can turn negative and lead to the TWFE estimator having the opposite sign of all individual comparisons, or at least not representing the policy relevant parameter of interest (Roth et al. 2023). A number of approaches have been developed to mitigate these problems. These rely on slightly varying assumptions and differ in their strengths and weaknesses (see Butts and Gardner 2022, for a nice illustration of some common estimators).

Parallel trends. In DiD, the parallel trends assumption replaces random assignment as known from randomized experiments. Most methods for staggered DiD still rely on a variant of the parallel trends assumption. Certain estimators (e.g. Callaway and Sant'Anna 2021) allow to relax it into a conditional parallel trends assumption: Controlling for certain pre-treatment observables, treated and control groups would have evolved in parallel absent the treatment. In our baseline estimations, we assume unconditional parallel trends of the untreated potential outcomes of municipalities treated with IMC and those remaining untreated.

Since municipalities decide individually whether to move into IMC, there is potential to self-select into treatment based on municipality characteristics. If these characteristics are correlated with the post-treatment potential outcomes, the parallel trends assumption would be violated. In order to take care of this issue, we test the predictive power of a number of municipality characteristics for treatment time and status. We then use methods which allow to control for those characteristics which are predictive of treatment. In doing so, we rely on a parallel trends assumption, *conditional* on these characteristics. As a robustness test, we apply a matching method to balance important variables between treatment and control municipalities.

The parallel trends assumption cannot be tested statistically in a direct way, as it is an assumption about unobserved potential outcomes. However, pre-trends can be used to test jointly for the presence of non-parallel trends pre-treatment and anticipation of the treatment (De Chaisemartin and D'Haultfœuille 2020). Since anticipation can be taken care of relatively easily in practice by redefining the treatment time to the earliest time where anticipation could arguably become a problem, still rejecting this "placebo test" in this anticipated treatment setting would give us a serious warning about the presence of non-parallel trends.

No anticipation. This assumption requires that for all periods until treatment, the treated potential outcome of the (later to be) treated units is the same as the untreated potential outcome of the same units (Callaway and Sant'Anna 2021).

Stable unit treatment value assumption. This assumption implies that in a setting such as ours, there are only two potential outcomes that units can take on: One for being treated, one for not being treated. Typically, this assumption is violated when there are general equilibrium effects, spillovers or externalities between units. Furthermore, it can be violated by measurement error in the treatment or outcome variable.

Correct model specification for $Y(0)$. Imputation methods for staggered DiD like Borusyak, Jaravel, and Spiess (2024) and Gardner (2022) require an additional assumption, namely that the model used to impute the counterfactual (untreated) outcome for the treated is correctly specified.

4.1 Interpretation of Event Study Results

Econometricians have recently called on applied researchers to pay more attention when interpreting event studies from the new staggered DiD estimators. In particular, they advice against comparing event-study estimates created by the estimators in De Chaisemartin and D'Haultfœuille (2020), Callaway and Sant'Anna (2021) and Borusyak, Jaravel, and Spiess (2024), particularly those estimates in the pre-treatment periods, to the traditional dynamic TWFE event study coefficients. Instead, the pre-trends should only be used as individual falsification exercises on parallel trends, and researchers should not look for a kink at $t = 0$ to conduct visual inference (Roth 2024).[5]

For the TWFE estimator, the event study (for both pre- and post-treatment periods) compares the deviation of the treated and untreated averages for each individual period. This difference is then compared to the same difference in period 0 - "long differences" (Roth 2024). Callaway and Sant'Anna (2021) also calculate "long differences" post-treatment, but their pre-treatment coefficients are "short differences". That is, they compare each pre-treatment period just to the previous pre-treatment period (Roth 2024). Borusyak, Jaravel, and Spiess (2024) calculate the pre-treatment coefficient comparing any period to the earliest pre-treatment period. The post-treatment coefficients illustrate the deviation of the treated and their imputed counterfactuals in comparison to the average deviation pre-treatment. To enourage looking at pre-trends estimates of the individual estimators separately, we display the estimates in separate panels.

5 Baseline results

In this section, we discuss our baseline results. Table 2 provides the results of IMC adoption on three different waste management outcomes: The share of selectively collected waste in total waste (column 1); the natural logarithm of per capita weight of residual waste (2) and the natural logarithm of per capita total waste (3). Moving into IMC was associated with a significant increase in separation rates of about 4 percentage points or around 12 percent compared to the 2009 average of 33% separation. The natural logarithm of residual waste per capita is highly significant, suggesting reductions of about 11 to 14 percent (.12 to .15 log points). The effect on the natural logarithm of total waste per capita is insignificant.

[5] Arkhangelsky and Imbens (2024) go further and advice against using all estimators together, given their different assumptions and different strengths to investigate particular heterogeneities.

Table 2: Average Treatment Effect on the Treated (ATT) of IMC adoption on environmental metrics of waste management. Standard errors in parentheses.

	(1)	(2)	(3)
Outcome Variable	Separation	ln(residual/cap)	ln(waste/cap)
Callaway & Sant'Anna	3.74***	-0.122***	-0.006
	(1.401)	(0.042)	(0.017)
Sun & Abraham	3.74***	-0.122***	-0.006
	(1.327)	(0.04)	(0.016)
Borusyak et al.	4.332***	-0.146***	-0.02
	(1.389)	(0.041)	(0.017)
Gardner	4.332***	-0.146***	-0.02
	(1.424)	(0.042)	(0.018)
nobs.	2176	2176	2176

Significance levels: * p<0.1, ** p<0.05, *** p<0.01

Figure 2 provides the event study for the separation rate and for each of the four staggered DiD estimators, plus the TWFE. None of the pre-treatment trends are significant, except in the TWFE estimator. However, we cannot rule out all concerns, as some of the confidence intervals are quite large, and the point estimates offer some indication that there is anticipatory behaviour. After treatment, the first four period effects are statistically different from zero also individually.

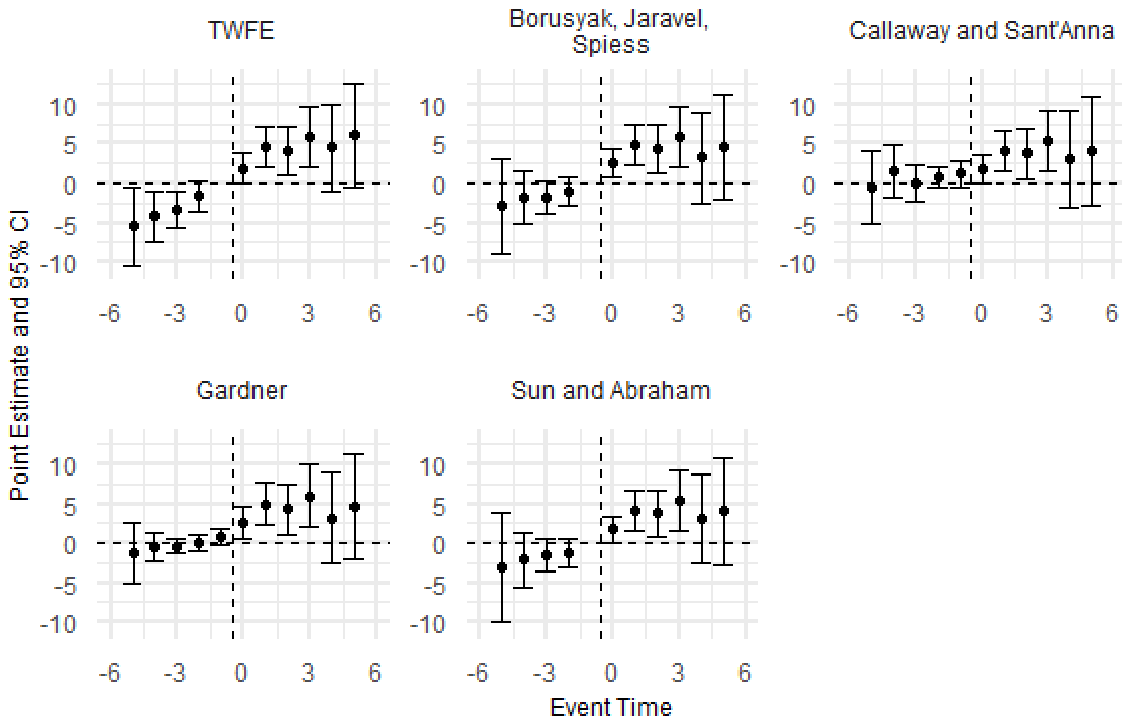

Figure 2: Event-study plot of the effect of IMC on waste separation

For the logarithm of residual waste per capita in Figure 3, the concerns mentioned previously are somewhat aggravated, with some pre-treatment estimates either at the very edge of statistical significance, or even significant at 5% level. The picture for the post-treatment period is as described above, with the effect in the post-treatment period being very clean and significant.

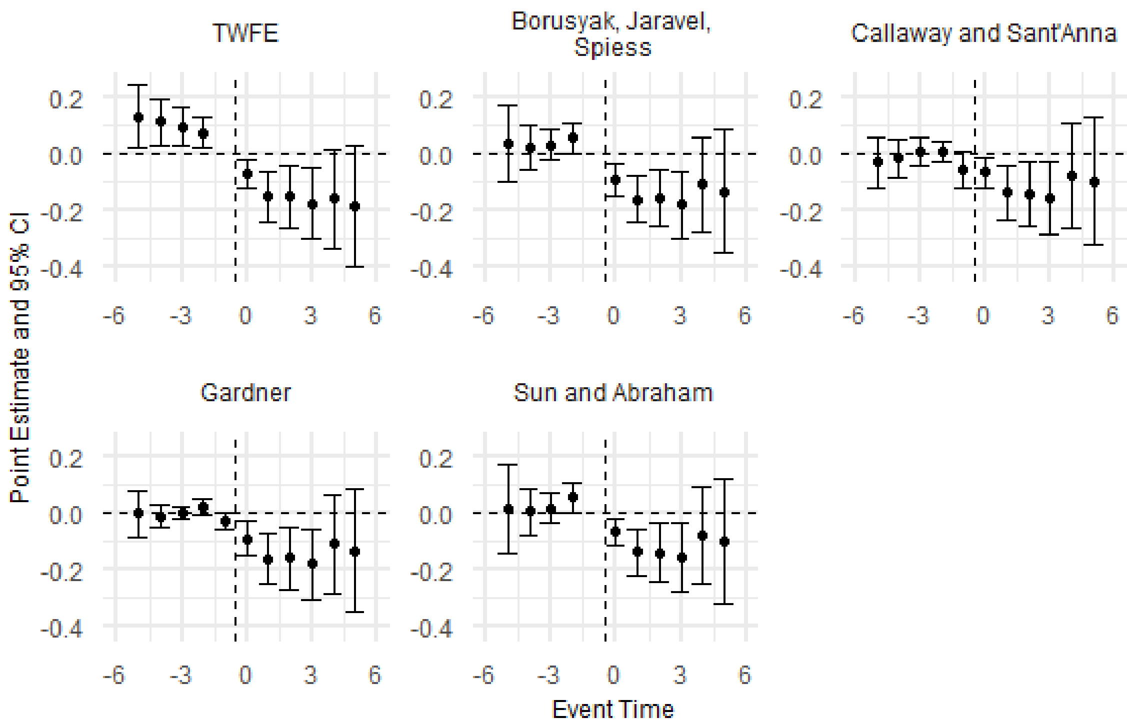

Figure 3: Event-study plot of the effect of IMC on log residual waste per capita

For the event study of the natural logarithm of total waste per capita in Figure 4, the pre-trends look somewhat erratic, and there is only a very small and significantly negative individual period effect in the first period after treatment, limited to single estimators. Thus, while moving into IMC is associated with higher separation rates and lower refuse weights per capita, some concerns regarding the pre-treatment trends remain. In a next step, we will document that this association was only present in a sub-period of the sample, before trying to deal with concerns regarding causal identification when unconditional parallel trends may not hold.

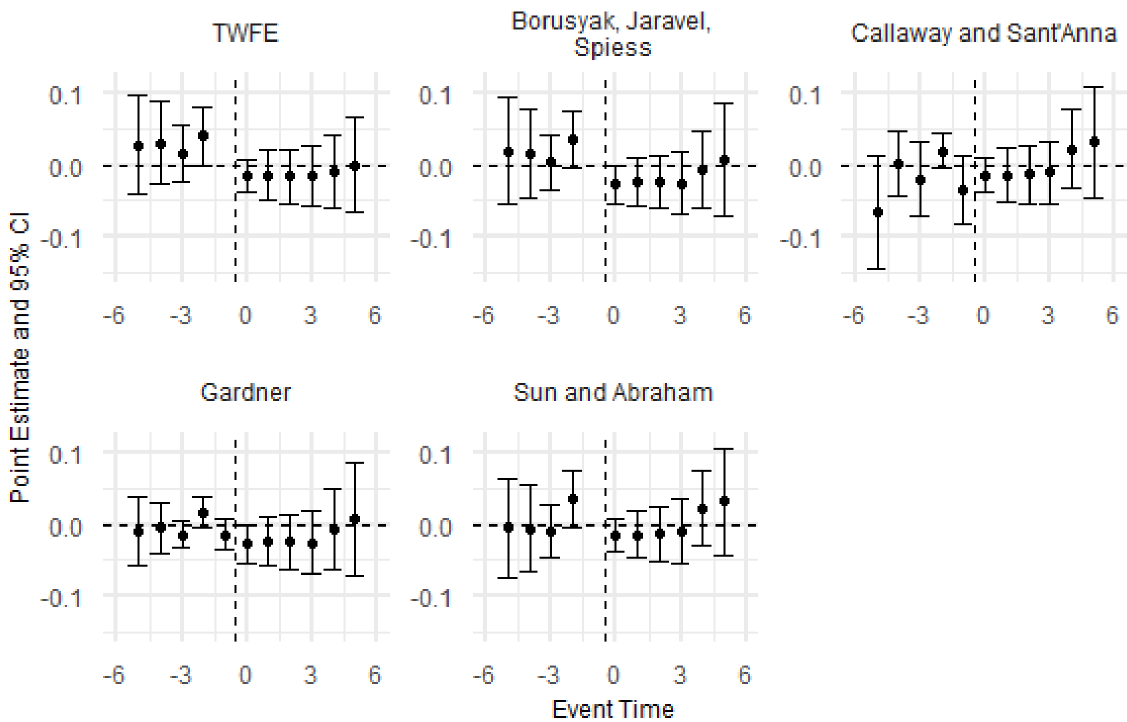

Figure 4: Event-study plot of the effect of IMC on log total waste per capita

5.1 The role of the landfill tax

Starting in 2017, Catalonia increased its landfill tax levied on municipalities significantly, from about 18 Euros to over 47 Euros per tonne in 2020. Jofre-Monseny and Sorribas-Navarro (2024) provide suggestive evidence that the landfill tax was behind large increases in selected collection of waste. We investigate the role of IMC in this story by using the flexible aggregation procedures in Callaway and Sant'Anna (2021) to combine the individual treatment effects to calendar year effects instead of an overall ATT. Note that the Callaway and Sant'Anna (2021) estimator was rather on the conservative side of the estimators applied previously. As Table 3 below shows, the calendar year treatment effects for separation and the logarithm of residual waste per capita are only large (and with the expected sign) in the periods 2018, 2020 and 2022, and only significant at 5% level in periods 2020 and 2022. Thus, the landfill tax seems to have modified the advantage of IMC in dealing with environmental challenges in waste collection.

Table 3: Effect of IMC on waste management outcomes, heterogeneity by calendar year. Standard errors in parentheses

year	Separation	ln(residual/cap)	ln(waste/cap)
2011	4.437	-0.117	-0.013
	(3.73)	(0.094)	(0.036)
2013	-0.484	0.02	0.018
	(1.518)	(0.033)	(0.025)
2014	0.469	0.012	0.026
	(1.158)	(0.026)	(0.021)
2016	0.606	-0.017	0.002
	(1.018)	(0.027)	(0.016)
2018	4.013*	-0.114*	-0.017
	(1.736)	(0.051)	(0.018)
2020	5.761**	-0.184**	0.003
	(2.167)	(0.075)	(0.024)
2022	7.465***	-0.283***	-0.036
	(2.274)	(0.078)	(0.026)

Significance levels: * p<0.1, ** p<0.05, *** p<0.01

To corroborate this finding, we also re-estimate the standard staggered DiD specifications from before, using only the treatment groups which were treated after the hike of the landfill tax (2018, 2020, 2022) and when this hike could have been expected (2016).[6] The corresponding results are shown in Chapter 9.1 in the Appendix and are consistent with the results presented above,

[6] The landfill tax was hiked most strongly in 2017, but to deal with possible anticipation and be conservative regarding the fact that it was almost doubled already in the previous years, we use 2016 as a cutoff date here. If we run the same specifications with 2018 as the cutoff, we lose about half of all switchers, but the results are qualitatively the same, also in terms of significance, and quantitatively very similar; results for these estimations are available upon request.

suggesting that moving into IMC was associated with larger environmental benefits after the hike of the landfill tax.

6 Possible Violations of Parallel Trends

Our parallel trends assumption states that the outcome of each group of treated municipalities would have evolved, in the absence of IMC treatment, in the same way as municipalities being treated later or not at all. However, given municipalities can select into IMC, this might not be a priori reasonable to assume here. In particular, we are concerned that municipalities could select into treatment based on their untreated potential outcome after the treatment (see Ghanem, Sant'Anna, and Wüthrich 2024). In the absence of a suitable instrumental variable to address the issue, we stress-test our results using a method to account for possible selection into treatment. First, following Hoynes and Schanzenbach (2009) and its refinement for IMC in Elston, Bel, and Wang (2024), we test whether a set of baseline variables found to explain IMC engagement in previous studies can explain also the *timing* of treatment in our setup. If so, we use this information to re-estimate the treatment effect by assuming that parallel trends holds, but conditional on these variables. By doing so, we can account for the possibility that IMC was adopted non-randomly, and that these drivers of non-random treatment assignment also lead to a different post-treatment potential outcome evolution.

Note that what we try to predict here is not only whether a municipality will join IMC at all, but when it will do so. Thus, while we can rely on the literature to some extent, we need to go beyond it, as it has so far only investigated general drivers of IMC. The most important pre-treatment variable we use for these exercises is the population size of the municipality, which has been shown to be the main driver behind IMC (Bischoff and Wolfschütz 2021; Bel and Warner 2016). Furthermore, we include sociodemographic information (population share aged 14 and below, 65 or more, tertiary education degree) to account for potential demographic drivers in public opinion, which could both promote / restrict co-operation and environmentally efficient waste policies. In the literature, Strebel and Kübler (2021) finds that age is associated with less willingness to engage in IMC.

We also include the number of tourist beds as a share of population, because tourism as a local phenomenon may lead municipalities to adopt IMC earlier to react to seasonal fluctuations in waste generation, and may also make adoption of better waste policies more urgent (or more difficult, for that matter). We include the share of center-left parties, as voters with green, alternative or left ideology are more open to IMC (Strebel and Kübler 2021), and because in our context of Spain, support for green policies decreases from left to right.[7]

One key factor for which we cannot control because of a lack of available data is the pre-treatment cost trajectory. We would theoretically expect municipalities with worse cost developments to select into IMC earlier, as they may be pushed into it by the prospect of cost reductions in IMC. But their higher costs should make them more unlikely to implement measures for higher waste selection post-treatment. Thus, we expect that any bias resulting would push our results *towards zero*. If IMC makes even municipalities negatively selected on cost efficiency more likely to increase waste separation, this would be a strong indication that IMC is effective. However, the landfill tax may have modified this tradeoff; we will discuss this issue later.

To identify the variables whose pre-treatment values are associated with treatment timing, we use two methods. We first regress the year of treatment on the explanatory factors discussed above (see results in Table 4). We repeat this procedure with a Cox proportional hazard model (Table 5), which allows us to also take into account those municipalities which have not yet joined IMC. Both models find a significant effect at 5% level of tertiary education, population size and centre-left vote share. Tourist beds per capita is significant at 10% level only in the Cox model. We thus proceed with three variables as controls, but also provide results with all controls as a robustness test.

[7] We use a more comprehensive definition of centre-left instead of green parties, because defining the latter according to the method by Cerqua, Fiorino, and Galli (2024) is very challenging in Catalonia: During the sample period, some large centre-left parties such as Esquerra Republicana and PSC have moved their position on environmental issues as indicated by the Chapel Hill Expert Survey in opposite directions.

Table 4: Predicted factors driving the timing of IMC adoption, OLS model

	coef	se	t	p
(Intercept)	9.953696	4.441083	2.241	0.026
Tertiary education	-0.085636	0.028817	-2.972	0.003
Pop. aged 14 and below	1.895348	14.615178	0.130	0.897
Pop. aged 65 and above	5.718251	8.403664	0.680	0.497
Population size	-0.000015	0.000006	-2.349	0.020
Tourist beds per capita	-0.630423	0.383737	-1.643	0.102
C-left parties’ vote share	-10.951047	3.309551	-3.309	0.001

Table 5: Predicted factors driving the timing of IMC adoption, Cox proportional hazard model

	coef	se	z	p
Tertiary education	0.030644	0.010948	2.799	0.005
Pop. aged 14 and below	-1.097317	5.503125	-0.199	0.842
Pop. aged 65 and above	-2.263615	3.178063	-0.712	0.476
Population size	0.000004	0.000002	2.310	0.021
Tourist beds per capita	0.214635	0.120535	1.781	0.075
C-left parties’ vote share	4.054706	1.314515	3.085	0.002

6.1 Parallel Trends Conditional on Pre-Treatment Covariates

We first re-estimate the treatment effect, conditioning on the three significant pre-treatment variables (population size, share of highly educated and centre-left party vote share). When including these covariates in the Callaway and Sant’Anna (2021) estimator, Table 6 illustrates that IMC may at most have reduced residual waste per capita very slightly (just significant at the 10% level), with the other variables displaying relatively erratic movements in the pre-trends (see Figure 11 in the appendix) and strongly insignificant effects.

The qualitative picture is very similar if we condition parallel trends in addition also on tourism, younger and older population share. The results are presented in Table 10 in the Appendix, and again the effect on log refuse is significant at 10% and on the cusp of significance at 5%, while the effect on all the other variables is insignificant, and the event studies in Figure 12 in the Appendix likewise fluctuate and are not markedly more stable than when only including significant controls.

Table 6: Effect of IMC on different variables under a parallel trends assumption conditional on population, education and political ideology. Standard errors in parentheses.

	Separation	ln(residual/cap)	ln(waste/cap)
	1.397	-0.09**	-0.019
	(1.55)	(0.045)	(0.02)
nobs.	2176	2176	2176

Significance levels: * p<0.1, ** p<0.05, *** p<0.01

6.1.1 Effect decomposition by calendar year

The effects of IMC on separated waste and the natural logarithm of residual waste per capita disappeared or at least were not systematically significant at 5% in the whole sample, once we include baseline covariates. However, we found in the previous sections that the effects were only significant and large after the landfill tax hikes started. As we did before, we aggregate the single effects to calendar effects instead of an ATT. The results are presented in Table 7 below for the significant controls (and Table 11 for all controls in the Appendix). While the size of the effects is much smaller and less significant, the previous pattern can still be observed: Once the landfill tax started to be hiked around 2018, separation increases and the logarithm of residual waste per capita decreases, where the latter becomes significant at the 5% level. We also observe a smaller, but insignificant reduction in the logarithm of total waste per capita after 2018.

Table 7: Effect of IMC on separated waste and DtD, heterogeneity by calendar year. Standard errors in parentheses.

year	Separation	ln(residual/cap)	ln(waste/cap)
2011	3.658	-0.105	-0.015
	(3.784)	(0.091)	(0.041)
2013	-1.253	0.03	0.015
	(1.612)	(0.037)	(0.028)
2014	-0.652	0.021	0.021
	(1.506)	(0.035)	(0.023)
2016	-1.09	0	-0.01
	(1.556)	(0.037)	(0.018)
2018	1.139	-0.082	-0.038
	(2.069)	(0.057)	(0.02)
2020	2.653	-0.139	-0.012
	(2.259)	(0.074)	(0.028)
2022	4.266	-0.23**	-0.051
	(2.455)	(0.089)	(0.029)

Significance levels: * p<0.1, ** p<0.05, *** p<0.01

6.1.2 Switchers in the post landfill tax hike period

If municipalities select their waste policy when they join an IMC, but exert some inertia in these choices thereafter, it is imaginable that the municipalities which start to cooperate *after* the landfill tax hike are able to reap more of the benefits of IMC. This is because for these municipalities, choosing a new collection policy from the menu offered by the county council, or implementing a new campaign which has proven to be effective in other municipalities may imply the least marginal cost, given that they are in an overhaul of their waste policy anyway.

Table 8 documents the estimated effects of IMC on waste outcomes of switchers in 2016 and after if we only use controls which are significant predictors of IMC adoption. IMC increases separation by about 5 percentage points, and this is the result of the natural logarithm of residual waste being reduced, while the natural logarithm of total waste also declines. All of these three effects are statistically significant at the 5% level. However, since residual waste per capita declines by 22 percent, and the overall waste weight per capita by a much more modest 8 percent, the separation rate increases. As we document in Table 12, if we include all controls, the estimate of the effect of IMC stays very similar.

Table 8: Effect of IMC on different variables under a parallel trends assumption conditional on population, education and political ideology, only switchers post-landfill tax. Standard errors in parentheses.

	Separation	ln(residual/cap)	ln(waste/cap)
	5.008**	-0.247***	-0.081**
	(2.277)	(0.08)	(0.034)
nobs.	1005	1005	1005

Significance levels: * p<0.1, ** p<0.05, *** p<0.01

Looking at the event studies in Figure 5, we see that the pre-trends are of least concern for the natural logarithm of residual waste per capita, where two event study point estimates pre-treatment center exactly on zero and confidence intervals are narrow. Selection becomes significant at the 5% level in the second period after treatment, the logarithm of residual waste per capita, as well as total waste per capita periods one and two post-treatment.

The event studies including all controls provide a very similar picture, with the main exception that the total waste effect is slightly smaller in size, the effect on residual waste slightly bigger and the pre-trends for selection look more favorable to the conditional parallel trends assumption (see Figure 13 in the Appendix).

When comparing the size of the causal effect of IMC in a setting with a landfill tax with other studies, joining IMC increases separation rates by about 5 percentage points, or a seventh of what Jofre-Monseny and Sorribas-Navarro (2024) report as the effect of DtD implementation. It is also about the same as the average effect of the landfill tax increase itself in their study. Furthermore, the effect of IMC is about half of the effect of a green election platform victory (Cerqua, Fiorino, and Galli 2024).

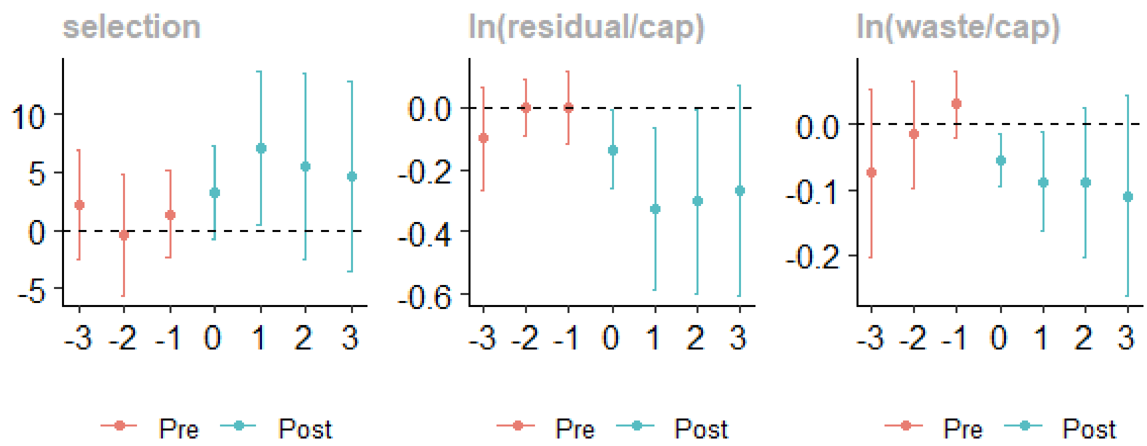

Figure 5: Event studies for effect of IMC on different variables under a parallel trends assumption conditional on population, education and political ideology, only switchers post-landfill tax

We tested the robustness of our results using Mahalanobis distance matching. The corresponding results tables and event study figures are provided in Appendix 9.5. The results are very similar to the ones presented here, with only the effect of IMC on the natural logarithm of refuse being significant consistently, and the effect on the other variables never, when all switchers are included. Also similarly to the results above, the event studies are not extremely stable, and thus provide a cautionary tale preventing us from drawing strong conclusions for the whole sample of switchers.

However, for those switchers moving into IMC after the landfill tax hike, we again find much more consistently significant, and larger results on the logarithm of residual waste per capita, and this time also on the separation rate. The only difference to the exercise with conditional parallel trends above is that the natural logarithm of total waste per capita is insignificant. For all variables, the pre-trends in the event studies look unproblematic (see tables and figures in Appendix 9.6).

6.2 Did the landfill tax change who begins to cooperate?

To be sure that our previous result of reductions in refuse waste and increases in selection can be attributed causally to IMC in a context of a high landfill tax, we need to rule out one more issue:

Instead of modifying the effect of IMC on the environmental performance of waste collection, the increase in the landfill tax could have pushed more of the badly performing municipalities into IMC, but those would have improved their waste management anyways, given the incentives provided by the landfill tax. We use three pieces of data to support our previous claim that the landfill tax made IMC more environmentally friendly than the counterfactual.

First, we calculate the number of municipalities that switched to IMC in each year. We find that if there was a change in the years following 2017, adoption of IMC actually declined, from about 13 per new survey to about 9. Even considering that the number of not-yet IMC municipalities has been reduced through IMC adoption, this results in a reduction in adoption.[8] Nonetheless, while the landfill tax has not increased the adoption of IMC, the aggravated fiscal strain caused by the higher landfill tax may have pushed those with particularly low environmental performance to join, while others could have been discouraged for any other reason. Then, if these underperforming municipalities would have acted anyways given the strong incentive provided by the landfill tax, our effect would be biased upwards.

In a second step, we therefore compare baseline waste generation and selection in municipalities joining IMC after the tax hike to their matches remaining outside after the tax hike. According to our data, municipalities remaining outside IMC underperformed on waste separation, generated more waste and consequentially also more residual waste at the beginning of this period. Thus, they are actually those where we would expect the tax to provide stronger additional fiscal pressure to join IMC, and incentive to reduce residual waste.

Thirdly, we compare the reaction of municipalities always cooperating to those never cooperating. We find that municipalities always in IMC reacted more quickly and strongly to the tax hike than those that never cooperated. When splitting the sample into small (population below 5’000) and large municipalities, we find that a jump in selection rates is visible in both samples (Figure 6).

[8] In addition, none of the municipalities joined a county of mancommunity created after the landfill tax started to be hiked, so the tax did not enable municipalities to join new cooperating entities with different characteristics either.

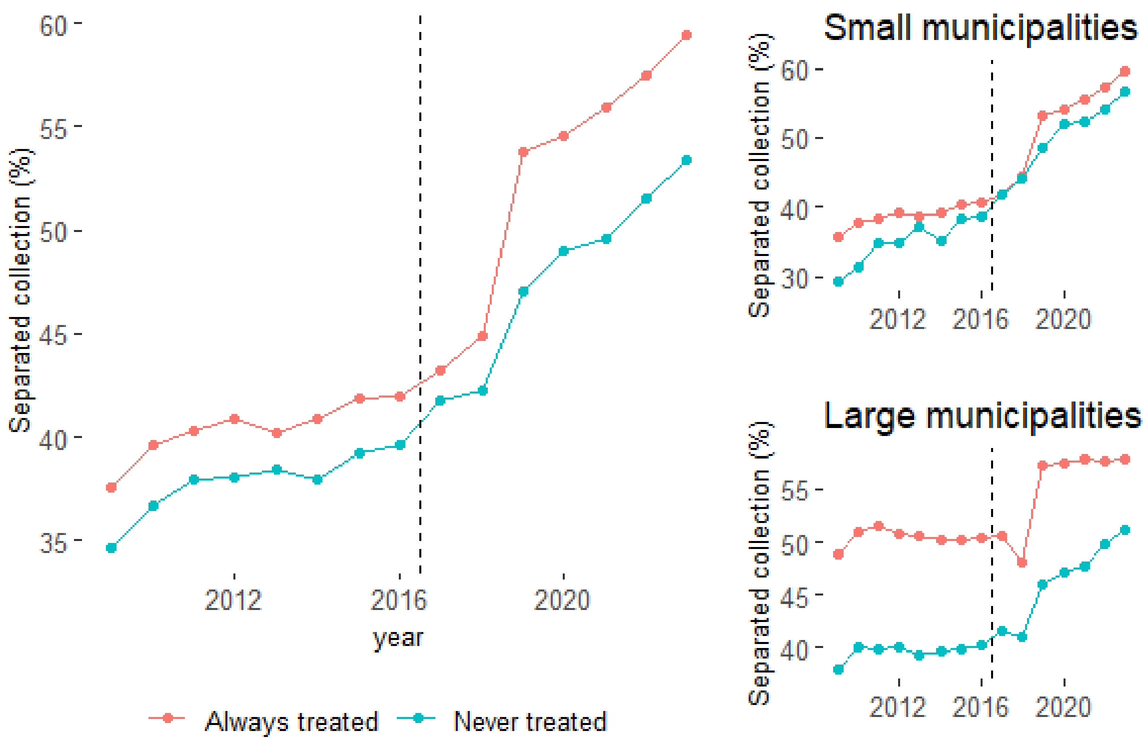

Figure 6: Evolution of separation, comparison of always treated and never treated municipalities.

For the natural logarithm of residual waste, the effect is a bit less pronounced. However, particularly smaller IMC-municipalities were reducing refuse waste more slowly than those providing the service standalone before the landfill tax was hiked, and their reduction path became steeper once it was hiked, as depicted in Figure 7. This offers further indication that the landfill tax modified how IMC municipalities behaved, even those not newly switching into IMC.

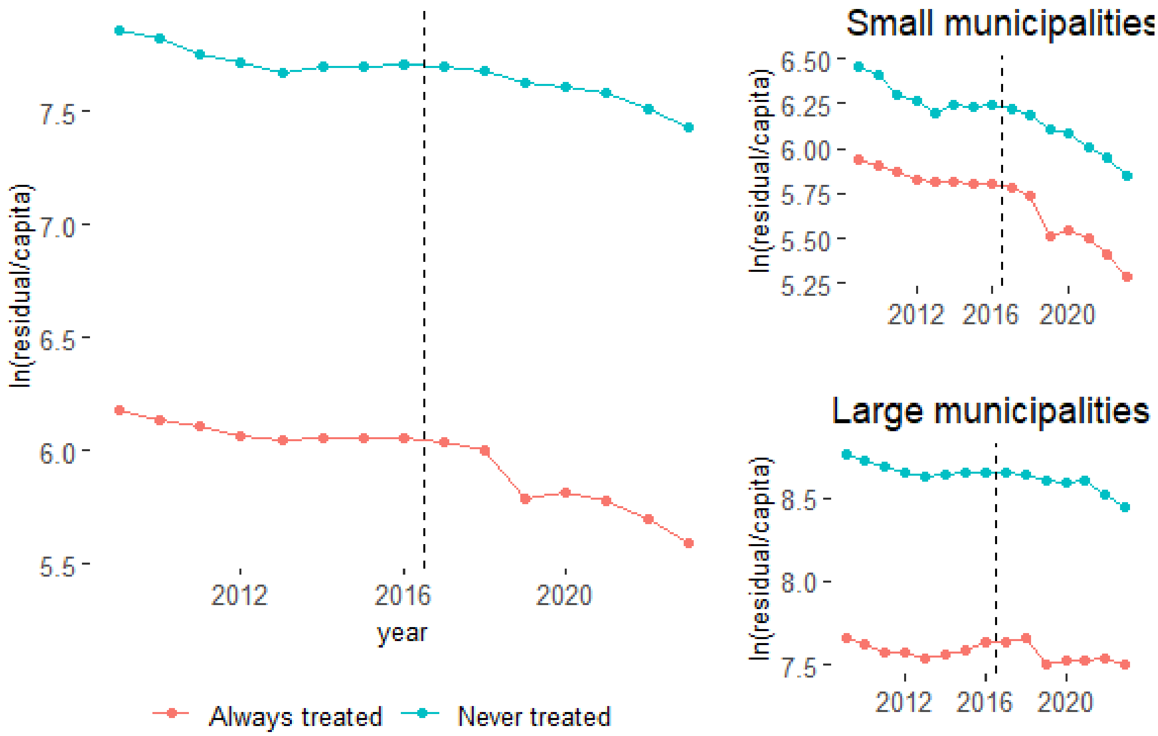

Figure 7: Evolution of the logarithm of residual waste per capita, comparison of always treated and never treated municipalities.

While we might be somewhat concerned by the big gap in baseline selection rates between IMC- and non-IMC municipalities in the sample of large municipalities, our switchers throughout the whole period are overwhelmingly below 5.000 inhabitants. Thus, we expect them to behave similar to smaller municipalities, where the difference between IMC and standalone provision was small and declining before, but the landfill tax seems to have accelerated the increase in separation rates more for co-operating municipalities. Since at least some of those municipalities will have joined IMCs promoting or enabling waste selection policies, county councils have played are role.

7 Discussion and Concluding Remarks

In this article, we have shown that moving into inter-municipal cooperation is associated with significant increases in separate waste collection and correspondingly reduced residual waste. When accounting for possible violations of parallel trends because of selection into treatment by conditioning parallel trends on pre-treatment covariates, a large and robust effect survives only for the period after the hike of the landfill tax in 2017, and particularly for those municipalities switching after the landfill tax was already hiked. Since IMC adoption *decelerated* after the landfill tax was hiked, and since those municipalities joining IMC later were those with better performing waste management, we suggest that the effect has been driven by municipalities in IMC entities (mostly counties) improving the environmental performance in waste collection more strongly in response to the tax hike.

Municipalities in IMC may already have been closer to implement more environmentally friendly policy *before* the landfill tax was increased, if IMC allows to account for spillovers present in waste management, and because IMC entities may be more effective at applying for subsidies for high separation rates. But the landfill tax increase may have tipped the balance in favor of environmentally friendly policies or campaigns in IMCs, helping to outweigh the additional cost from these policies. In line with this, our data shows that IMC on its own has, if at all, not been very effective to deal with the environmental effects of jurisdictional fragmentation motivating our research. This suggests that it "takes more than one village", but not to internalize a large share of the environmental spillovers, but to effectively react to legislation by higher levels of government, in this case the landfill tax. As such, IMC serves as a complement to the landfill tax, increasing its effectiveness. In more general terms, our findings point to the need to think in depth about how capable agents and jurisdictions are to react to environmental taxation, and what structural changes on the ground can do to enhance such capabilities.

We find that joining IMC when there is a high landfill tax increases separation rates by about 5 percentage points. We do also find an impact of IMC on total waste, but just for switchers moving into IMC after the landfill tax was increased, and this result is not robust to a change in the matching / conditioning method. Such a result is surprising, because the policy solutions to increase recycling through measures in waste collection (using e.g. adjustments to collection time, proximity, collection technique or campaigns) seem much more straightforward than those to reduce waste generation. One explanation could be spillovers from waste recycling to waste reduction behavior; very similar spillovers have been documented in other cases (see Alacevich, Bonev, and Söderberg 2021; Abeshev and Koppenborg 2023), where increased separation of one waste component as a reaction to policy targeting selection in this component also affected separation of another component.

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9 Appendix

9.1 Baseline Estimations, Post-landfill tax switchers

Table 9: Average Treatment Effect on the Treated (ATT) of IMC adoption on environmental metrics of waste management. Standard errors in parentheses.

	(1)	(2)	(3)
Outcome Variable	Separation	ln(residual/cap)	ln(waste/cap)
Callaway & Sant'Anna	6.981***	-0.279***	-0.07**
	(2.117)	(0.082)	(0.03)
Sun & Abraham	6.981***	-0.279***	-0.07**
	(2.04)	(0.082)	(0.029)
Borusyak et al.	7.322***	-0.283***	-0.067**
	(2.049)	(0.083)	(0.029)
Gardner	7.322***	-0.283***	-0.067**
	(2.073)	(0.083)	(0.029)
nobs.	1005	1005	1005

Significance levels: * $p<0.1$, ** $p<0.05$, *** $p<0.01$

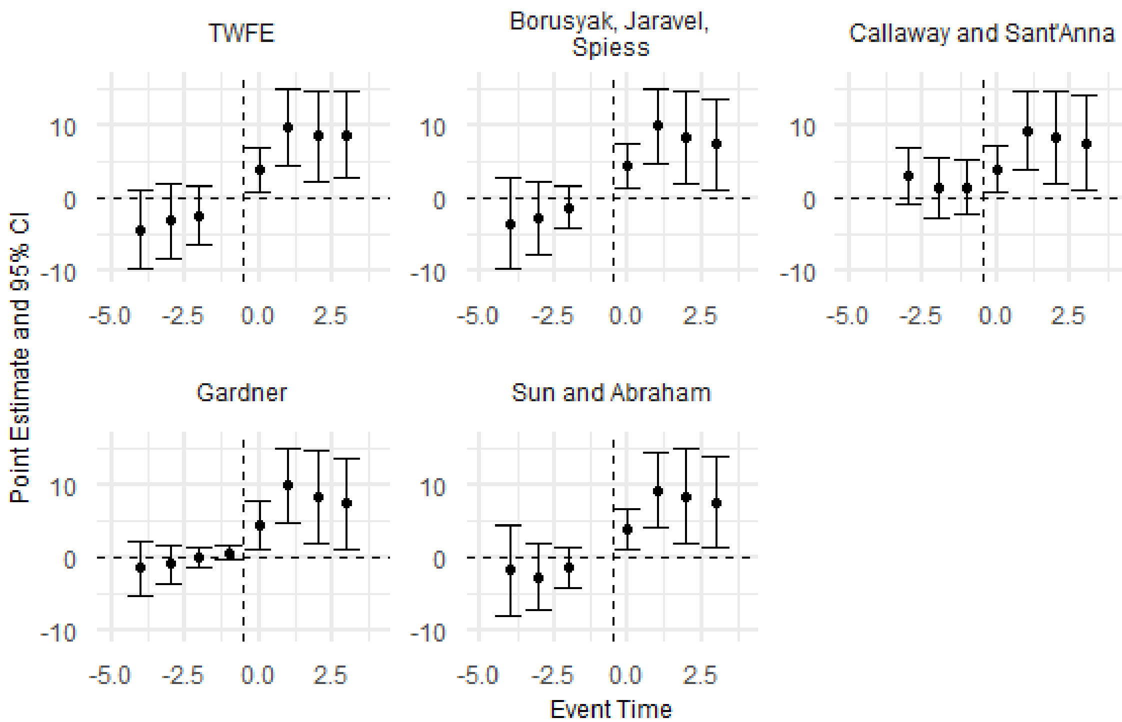

Figure 8: Event-study plot of the effect of IMC on waste separation, period after the landfill tax hike

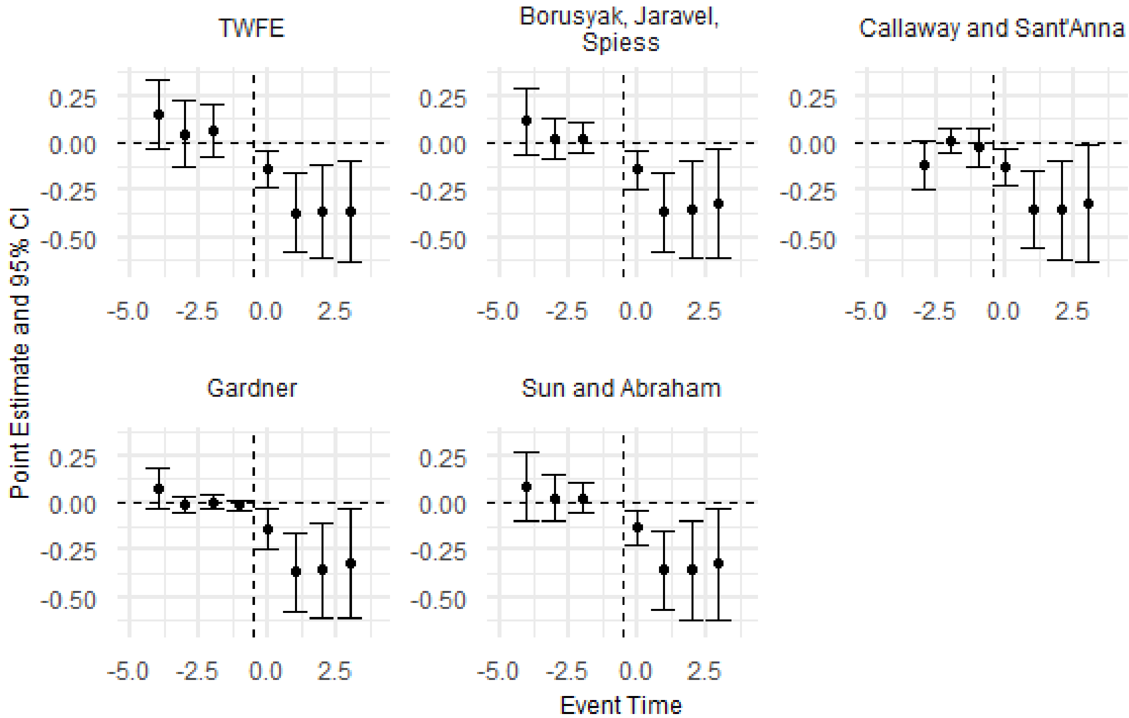

Figure 9: Event-study plot of the effect of IMC on log residual waste per capita, period after the landfill tax hike

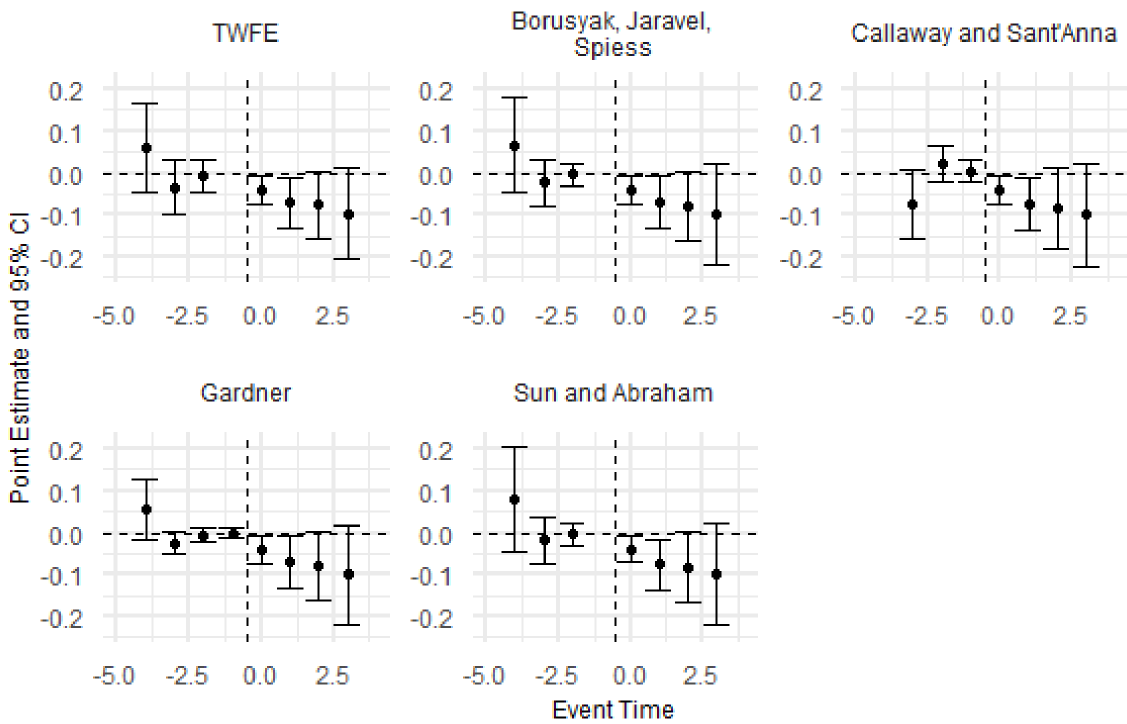

Figure 10: Event-study plot of the effect of IMC on log total waste per capita, period after the landfill tax hike

9.2 Difference-in-Difference estimation with conditional parallel trends

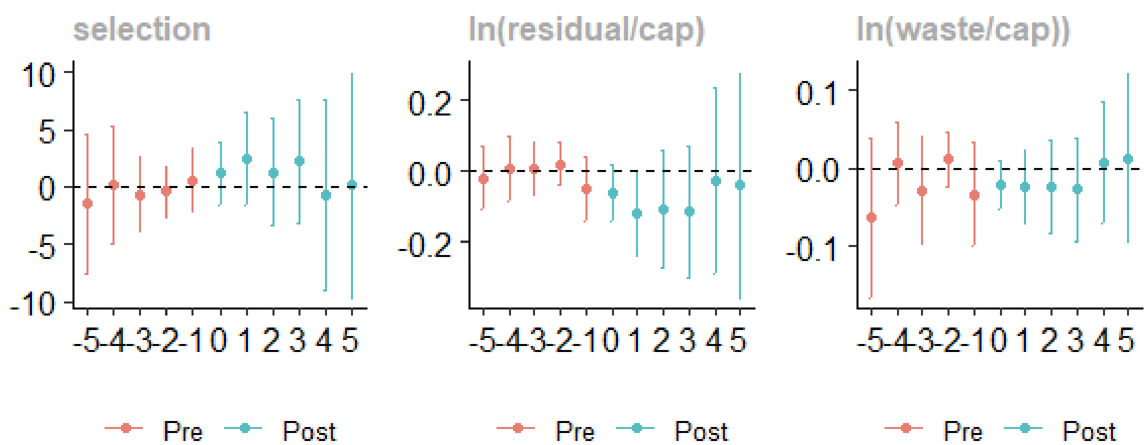

Figure 11: Event studies for effect of IMC on different variables under a parallel trends assumption conditional on population, education and political ideology

Table 10: Effect of IMC on different variables under a parallel trends assumption conditional on population, education, political ideology, demography and tourism. Standard errors in parentheses.

	Separation	ln(residual/cap)	ln(waste/cap)
	1.618	-0.091*	-0.016
	(1.579)	(0.047)	(0.018)
nobs.	2176	2176	2176

Significance levels: * p<0.1, ** p<0.05, *** p<0.01

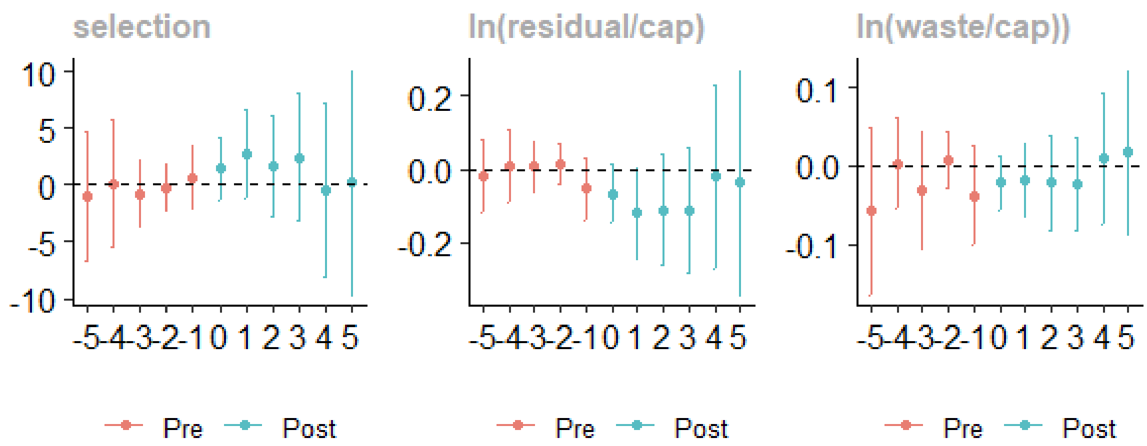

Figure 12: Event studies for effect of IMC on different variables under a parallel trends assumption conditional on population, education, political ideology, demography and tourism

9.3 Calendar Decomposition of conditional DiD estimator with all controls

Table 11: Effect of IMC on separated waste and DtD, heterogeneity by calendar year, parallel trends conditional on all control variables. Standard errors in parentheses.

year	Separation	ln(residual/cap)	ln(waste/cap)
2011	3.808	-0.106	-0.014
	(3.758)	(0.097)	(0.044)
2013	-1.163	0.029	0.015
	(1.677)	(0.037)	(0.028)
2014	-0.495	0.018	0.02
	(1.468)	(0.033)	(0.024)
2016	-0.807	-0.001	-0.006
	(1.43)	(0.034)	(0.018)
2018	1.42	-0.084	-0.034
	(2.078)	(0.053)	(0.021)
2020	2.924	-0.143	-0.01
	(2.292)	(0.075)	(0.029)
2022	4.431	-0.227	-0.044
	(2.486)	(0.088)	(0.029)

9.4 Conditional DiD estimator with all controls, only switchers post-landfill tax

Table 12: Effect of IMC on different variables under a parallel trends assumption conditional on population, education, political ideology, demography and tourism, only post-landfill tax hike switchers. Standard errors in parentheses.

	Separation	ln(residual/cap)	ln(waste/cap)
	5.338**	-0.254***	-0.078**
	(2.087)	(0.084)	(0.033)
nobs.	1005	1005	1005

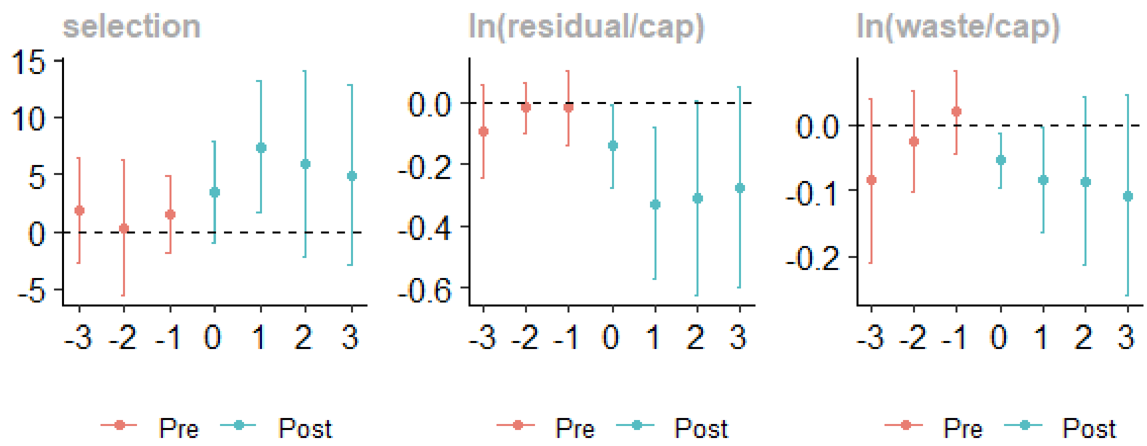

Figure 13: Event studies for effect of IMC on different variables under a parallel trends assumption conditional on population, education, political ideology, demography and tourism, only switchers post-landfill tax

9.5 Mahalanobis Distance Matching

Table 13: Balance table for Mahalanobis Distance Matching

	Means Treated	Means Control	Std. Mean Diff.
Tertiary education	30.55	30.72	-0.03
Population	4822.08	5849.00	-0.15
C-left vote shr.	0.54	0.54	-0.01

Table 14: Average Treatment Effect on the Treated (ATT) of IMC adoption on environmental metrics of waste management and DtD, control group matched based on Mahalanobis distance matching. Standard errors in parentheses.

	(1)	(2)	(3)
Outcome Variable	Separation	ln(residual/cap)	ln(waste/cap)
Callaway & Sant'Anna	1.656	-0.102**	-0.02
	(1.551)	(0.045)	(0.016)
Sun & Abraham	1.656	-0.102**	-0.02
	(1.501)	(0.043)	(0.018)
Borusyak et al.	1.927	-0.125***	-0.035*
	(1.571)	(0.044)	(0.019)
Gardner	1.927	-0.125***	-0.035*
	(1.604)	(0.046)	(0.019)
nobs.	1232	1232	1232

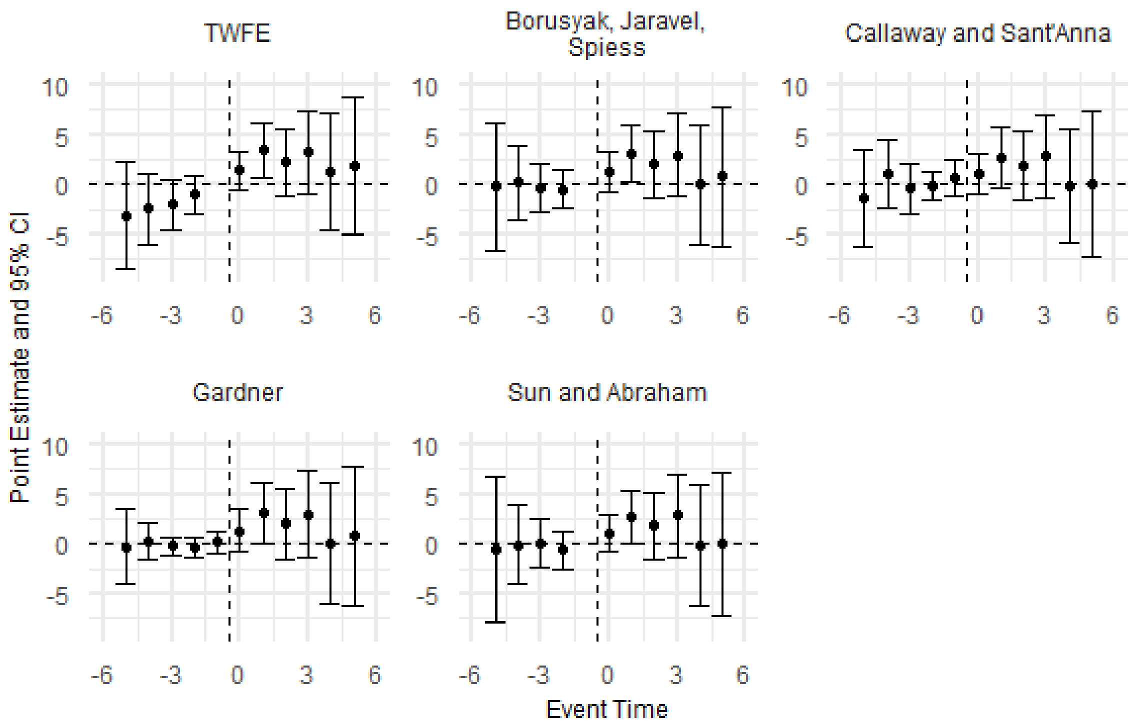

Figure 14: Event-study plot of the effect of IMC on the share of separated waste, control group matched based on Mahalanobis distance matching

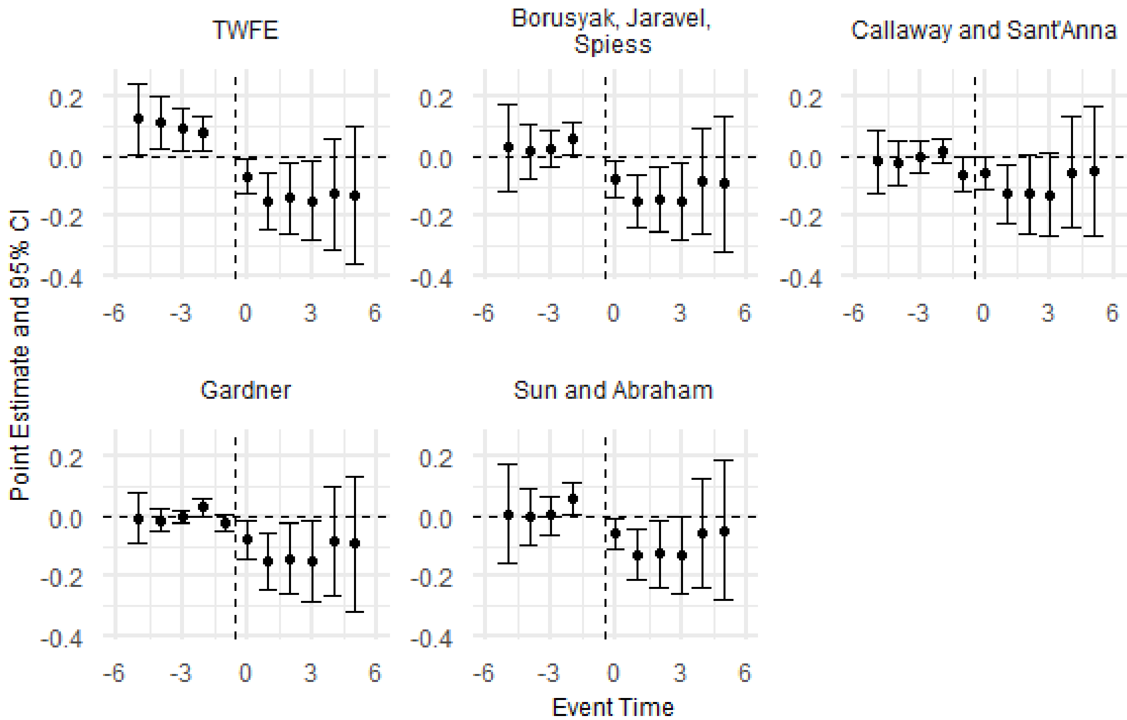

Figure 15: Event-study plot of the effect of IMC on ln refuse per capita, control group matched based on Mahalanobis distance matching

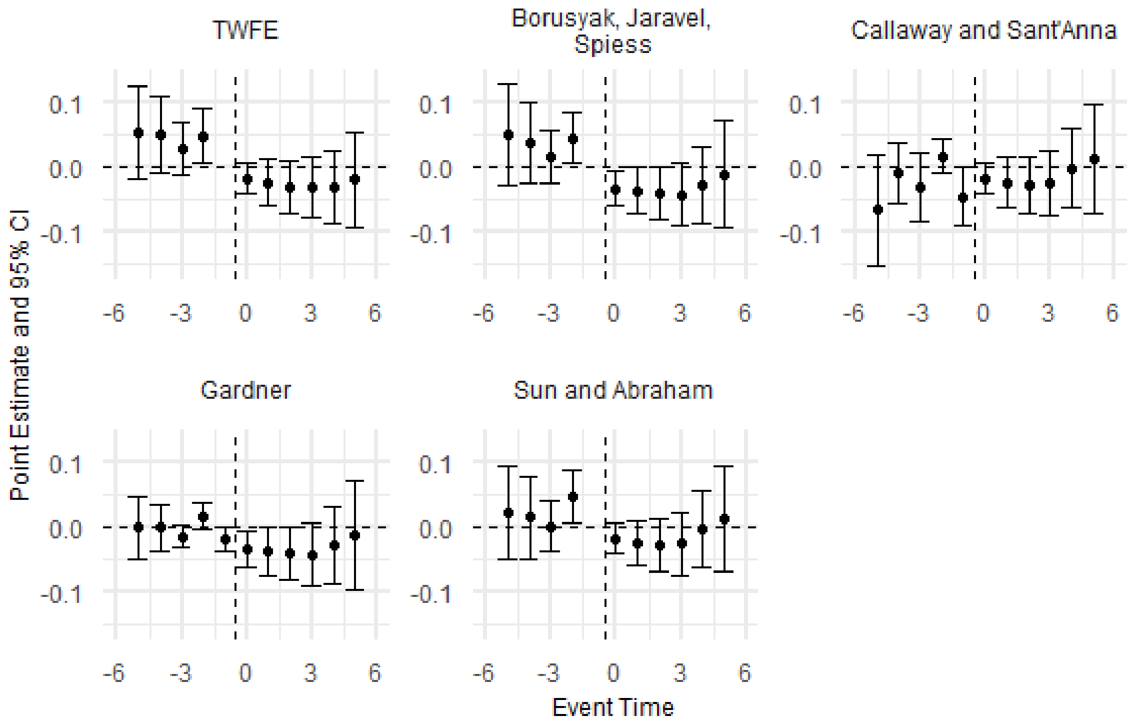

Figure 16: Event-study plot of the effect of IMC on ln total waste per capita, control group matched based on Mahalanobis distance matching

9.6 Mahalanobis Distance Matching, only post-landfill tax hike switchers

Table 15: Balance table for Mahalanobis Distance Matching, switchers post-landfill tax hike.

	Means Treated	Means Control	Std. Mean Diff.
Tertiary education	30.59	30.61	0.00
Population	4922.82	5789.39	-0.12
C-left vote shr.	0.53	0.53	-0.04

Table 16: Average Treatment Effect on the Treated (ATT) of IMC adoption on environmental metrics of waste management and DtD, only post-landfill tax switchers. Control group matched based on Mahalanobis distance matching. Standard errors in parentheses.

	(1)	(2)	(3)
Outcome Variable	Separation	ln(residual/cap)	ln(waste/cap)
Callaway & Sant'Anna	6.122**	-0.28***	-0.068*
	(2.381)	(0.095)	(0.036)
Sun & Abraham	6.122**	-0.28***	-0.068*
	(2.503)	(0.091)	(0.034)
Borusyak et al.	6.04**	-0.274***	-0.062*
	(2.396)	(0.087)	(0.033)
Gardner	6.04**	-0.274***	-0.062*
	(2.425)	(0.088)	(0.033)
nobs.	280	280	280

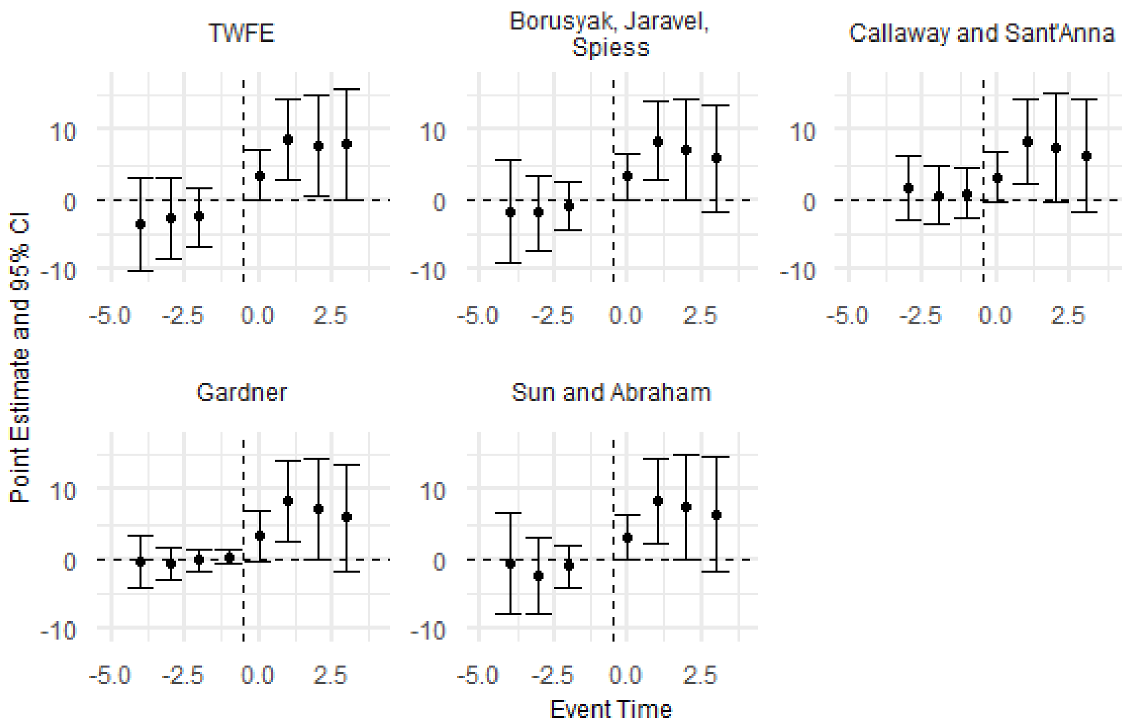

Figure 17: Event-study plot of the effect of IMC on separated waste, control group matched based on Mahalanobis distance matching post-landfill tax

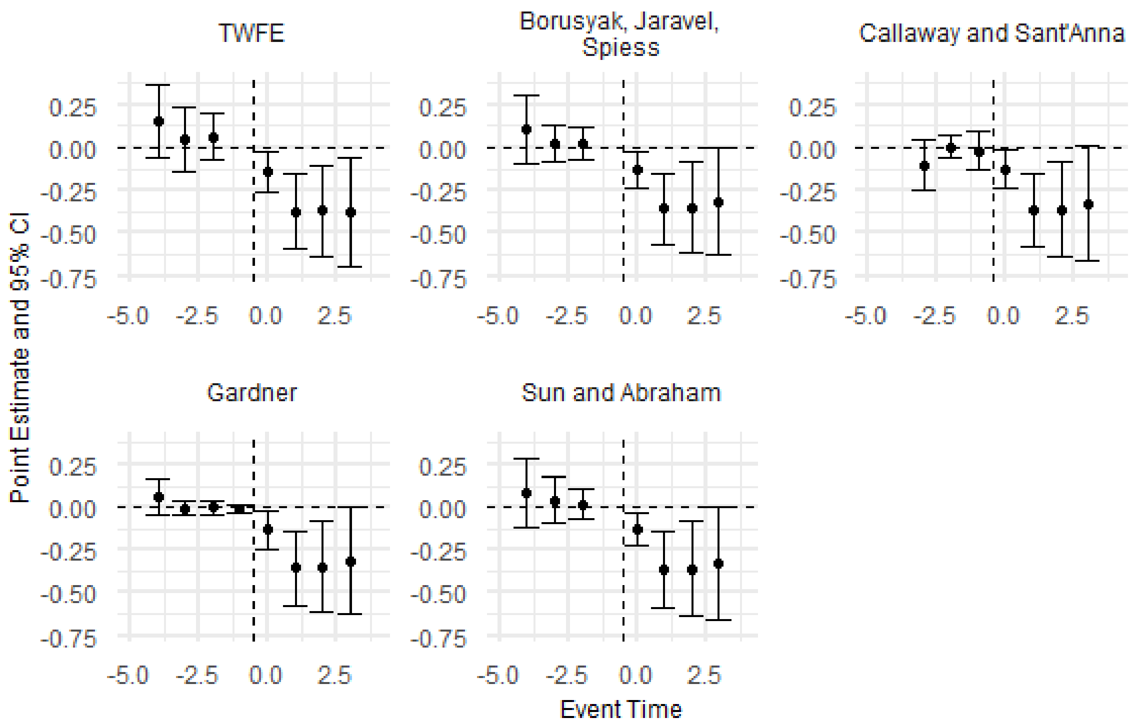

Figure 18: Event-study plot of the effect of IMC on ln refuse per capita, control group matched based on Mahalanobis distance matching post-landfill tax

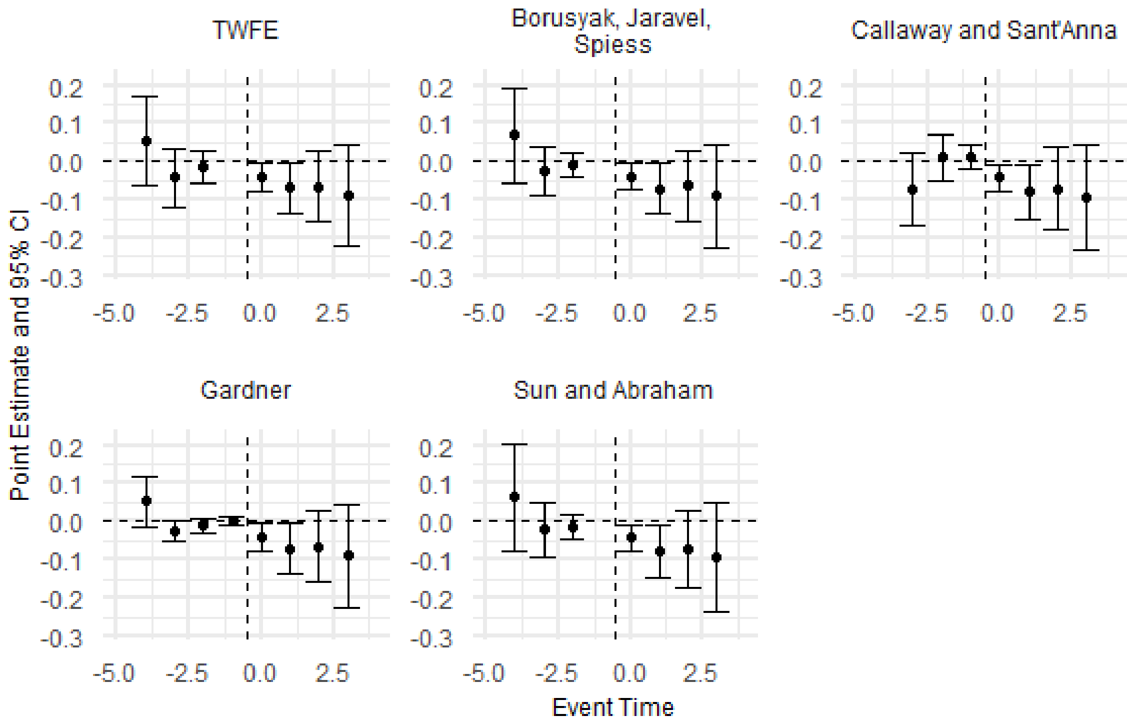

Figure 19: Event-study plot of the effect of IMC on ln total waste per capita, control group matched based on Mahalanobis distance matching post-landfill tax

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