Interactions Between Fixed and Mobile Recycling Facilities: Do Personal Norms Matter?*

Abstract

Solid waste management is today one of the most significant global environmental issues, as rapidly increasing production of disposable goods overcomes the capacity of available infrastructure. Recycling can help to reduce the level of pollution, while also reducing the amount of waste that goes to landfills, preventing their collapse. This paper designs and implements a field experiment aimed at evaluating the impacts of pecuniary and non-pecuniary incentives reducing the costs of households' participation in recycling schemes. Our intervention took place in southern Chile. We study the effect of providing a door-to-door service on recycling plastic and sorting waste by households once open-access street containers are available. Special attention is given to the interactions between both types of infrastructure. We also explore whether appealing to personal norms reinforces households' behavior regarding recycling plastic and waste sorting. Our results show that adding a door-to-door recycling service to a drop-off system increases plastic recycling, and both types of infrastructure are complementary. Results evidence the absence of reinforcement effects when normative messages are provided after introducing door-to-door recycling services and that mobile recycling infrastructure increases the amount of non-recyclable waste in fixed infrastructure. This is most likely due to the higher chance that people recycling through the door-to-door recycling service can be discovered as recycling improperly.

Keywords: Curbside collection system, fixed recycling infrastructure, information campaign, personal norms, plastic waste.

JEL classification: Q53, D10, C93.

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1. Introduction

The increasing solid waste generation and the pressure on waste management systems are among the major environmental challenges societies must face nowadays. International environmental statistics show that the amount of waste generation is rising along with the global population. By 2050, the total global waste is projected to reach 3.4 billion metric tons, with low-income nations experiencing a threefold increase (United States Environmental Protection Agency (EPA), 2020). In response to this pressing issue, promoting household recycling has become a prominent environmental objective in several countries.

Sorting waste for recycling is often considered an example of a voluntary contribution to a public good because it imposes costs to households associated with time and effort. In contrast, the environmental benefits of their contribution are non-rival and non-excludable (Huhtala, 2010). Thus, it is essential to understand what strategies and policies effectively increase households' participation in recycling schemes. Because people undertake efforts to allocate space and time to recycling activities, which could even increase household expenses (Bruvoll et al., 2002), the provision of recycling facilities has been identified as a key factor in reducing recycling costs in the household (Chen & Tung, 2010; Chong et al., 2015; Gilli et al., 2018; Miafodzyeva & Brandt, 2013; Rhodes et al., 2014). There is also evidence that the existence of recycling infrastructure does promote recycling practices, making them more appealing to households (Bernstad, 2014; Lee et al., 2017; Nainggolan et al., 2019; Sidique et al., 2010).

This study aims to assess the effects of mobile recycling facilities on plastic recycling and sorting in a southern city in Chile. Our intervention consists of implementing a mobile recycling service (door-to-door recycling system) once the fixed recycling infrastructure is already in place. Thereby, special attention is given to the interaction between mobile and fixed recycling infrastructure and the extent to which norm-based information calling for personal norms plays a role in reinforcing residential recycling among households.

Experimental evidence has shown that people recycle more when the recycling site is closer to the household and when they understand better how to sort their waste. For instance, DiGiacomo et al. (2017) designed two randomized field experiments with multi-family residential buildings and student residences, providing them with recycling containers and varying the distance from the door of each suite, finding that, for both recycling and compost, when the bins were located on each floor, closer to the suites instead of on the ground floor, the composting and recycling rates increased by 70%, and by 147% respectively. Also, when the recycling bin is nearer than the general waste bin, people tend to recycle more, and the effect is stronger the closer the recycling bin is to the waste generation point (Rosenthal & Linder, 2021; Zhang et al., 2016). Sörme et al. (2019) found that introducing colored bags for different types of materials in a recycling curbside collection system, making the classification more straightforward for households, increased the amount of sorted waste by 35% and decreased the amount of waste generation by 15%. Other studies have demonstrated that providing information about how to recycle is effective in increasing recycling participation and improving waste segregation (Pegels et al., 2022; Rhodes et al., 2014; Wadehra & Mishra, 2018).

Literature identifies three types of recycling facilities, which are often provided by local governments (excluding those that provide an economic incentive to households) (González-Torre & Adenso-Díaz, 2005; Struk, 2017): (1) recycling centers, (2) open-access street bins, and (3) door-to-door recycling systems. The first one consists of a specific location with various containers for different recyclable materials. It is operated with the support of some employees who help people sort and dispose of their recyclables properly. Upon disposal, waste is processed through mechanical cleaning and compacting. The second type of facility, open-access street bins, are containers located in public places in neighborhoods for the disposal of recyclable materials. Containers are available to all potential users, and there is no control over their operation. The third type of facility, door-to-door recycling service, consists of a collection system at the household level, where bins, sacks and bags may be provided for households, placed outdoors or indoors, and a truck removes the waste sorted for recycling (Dahlén & Lagerkvist, 2010). This system is the most convenient from a household perspective but is also the most expensive, requiring more time and higher resources from the local government. Comparing the effectiveness of different types of recycling facilities, Struk, (2017) evaluates the difference between drop-off sites and curbside collection systems to recycle plastic and paper materials in the Czech Republic. He found that curbside collection increases separation rates by almost 40% compared to drop-off sites. Sidique et al. (2010) analyze the effects of recycling and waste management policies on the recycling rate in Minnesota counties. They found that curbside recycling services and drop-off sites effectively increased the recycling rate only when implemented together. Still, they did not observe significant changes in recycling when these interventions were implemented separately. By evaluating the recycling programs in Sweden, Dahlén & Lagerkvist (2009) found that householders with door-to-door collection sorted their waste twice as much as those with only drop-off points. Best & Kneip (2011) also found that, in the case of Cologne, Germany, when the recycling system changed from a drop-off system to curbside collection, the recycling participation increased by 19% for plastic materials. In a study of Dutch municipalities, Gradus (2020) found that municipalities that have introduced curbside collection or increased the density of recycling centers also have higher collection rates. In comparing different recycling policies in the US, Saphores & Nixon (2014) show that curbside collection was more effective than drop-off collection centers, bottle bills and marginal pricing for improving household recycling. In contrast, a study by Starr & Nicolson (2015) for the Commonwealth of Massachusetts shows that curbside collection systems are effective only when combined with the Pay-As-You-Throw (PAYT) policy and when the curbside collection is implemented alone may be insignificant or hurt recycling rates.

Another brunch of the literature has been devoted to analyzing households' recycling decisions, showing that, although access to recycling facilities and the ease of the system are strong predictors of recycling participation, the sole availability of recycling does not necessarily imply that individuals will sort their waste (Dijkgraaf et al., 2021; Struk, 2017). Literature evidence that the existence of recycling facilities and economic incentives to recycle does not promote homogeneous behavioral responses, and the difference is especially relevant between those people who do not recycle and those who have already acquired the habit of recycling (Best & Kneip, 2011; Chong et al., 2015; Córdova et al., 2021). Thus, when individuals feel that there are enough recycling facilities and are satisfied with them, their behavior depends on their attitudes and beliefs towards waste segregation and recycling (Stoeva & Alriksson, 2017). This suggests that recycling efforts are linked to altruistic beliefs, the belief that this action benefits the environment, and self-perceptions of responsibility (Corrado et al., 2022). Thus, the desire to protect the environment and assist others are significant predictors of recycling engagement (Ali et al., 2020). In some contexts, intrinsic factors are stronger predictors of recycling participation than incentives based on external pressures (Botetzagias et al., 2015; Gilli et al., 2018; Halvorsen, 2008; Viscusi et al., 2011). Because of the relevance of personal norms, experimental studies have tested the effect of norm-based messaging and general information on recycling participation. For example, Chong et al. (2015) tested nine messages to engage households on recycling practices in Peru and found that none of the messages effectively increased recycling participation. On the contrary, Rhodes et al. (2014) used four types of messages. Also, they tested how the effects differed depending on the kind of facilities available to the surveyed households in Canada (drop-off sites in the neighborhood and big recycling centers). Their results show that, in general, the messaging strategy was effective, being the most effective (and enough) to provide basic instructions. Pegels et al. (2022) designed a field experiment where they sent envelopes with four types of content to improve sorting quality, avoiding the presence of non-recyclable materials: simplifying information, messages with social appeals, a magnetic calendar that served as a reminder, or all of the above. Findings indicated that all interventions decreased the prevalence of bags containing non-sorted waste.

Households' participation in recycling schemes depends largely on the waste management system's features, which is especially relevant in developing countries. In the case of Chile, waste collection and disposal services are managed at the municipality level, and recycling is not mandatory by the authority (Valenzuela-Levi, 2019). Moreover, in 140 of 345 cities in the country, more than 90% of the households are exempt from paying waste disposal fees. In 61 cities, the total exemption from payment of this fee is for 100% of the households (Center for Public Systems University of Chile & Ministry of Environment Government of Chile, 2020). In this context and in order to increase the recycling rate, many local governments have installed drop-off recycling bins in the streets to bring recycling closer to households and reduce travel costs that prevent them from recycling. Nevertheless, the increasing using of these containers and a low frequency of withdraws has also led to misuse, with overstuffed recycling bins and litter around them, questioning the effectiveness of this policy (Petersen & Berg, 2004). In this context, a door-to-door recycling system has emerged as a possible solution to these problems.

This research contributes to the existing literature in the following aspects. First, our experimental design considers establishing a baseline scenario by implementing a fixed collection recycling system in two neighborhoods of an urban area where previous access to recycling facilities was minimal. This strategy reduces a potential bias in the results that can emerge due to differences in relative experience between treatment and control groups from previous related interventions. Second, our design allows for assessing a potential substitution/complementarian effect between these types of infrastructure, an interaction that has not been extensively studied in the literature. Third, most of the previous studies focused on evaluating the provision of fixed recycling infrastructure in combination with behavioral levers. Our research design allows us to isolate the effect of the interactions between fixed and mobile infrastructure and evaluate the potential reinforcement effects arising from norm-based information in separate stages.

The remainder of the paper is organized as follows: In section 2, we provide the experimental design details. Section 3 presents the empirical strategy to achieve the research objectives. The results and discussion are presented in section 4. Finally, section 5 provides the main conclusions.

2. Experimental Design

2.1. Context[1]

The intervention took place in the city of Osorno, southern Chile. The city, with 161,460 inhabitants according to the 2017 Census, is the second more populated urban area in Los Lagos Region. Data from the Record of Emissions and Pollutant Transference of the Ministry of Environment of the Chilean Government for 2018 reveals that this city generated 71,929 tons of waste, equivalent to 0.45 annual tons per capita. From this amount of waste, only 222 tons (0.31%) were recycled, mostly glass (60.3%), with plastic representing 18.5% of total recycling materials. Osorno, as well as other cities in Chile, has a household waste collection system that allows households to dispose of their garbage at the municipal landfill. In the case of Osorno, the local municipality provides this service three times a week in the urban area. This service does not sort the garbage and does not intend to do any other processing except to dispose of it in the municipal landfill. The service charge is based on a flat tariff that depends on a fiscal appraisal of the house and is unrelated to the amount of disposed of waste at each collection. A large part of households are exempt from this charge due to their level of economic vulnerability. The recycling system is significantly less developed than the general waste collection system. It is mainly implemented by installing open-access containers in the streets, the most common are plastic and glass containers. Regarding recycling infrastructure, containers are primarily available in the city's eastern sector, and no recycling stations are provided in the city's western areas, except for some stations where it is possible to recycle only glass. The administration of the recycling system, as well as the decision of where to locate recycling infrastructure, is controlled by a private recycling company hired by the local municipality.

2.2. The Intervention

The intervention consists of designing and implementing a field experiment targeting two neighborhoods of Osorno City in southern Chile. For design purposes, two middle-income neighborhoods in the city's western sector were selected, one of which was regarded as the control group and the other as the treatment group. The neighborhoods were Mirasur (treatment group) and Ovejería Alto (control group), with 1,458 and 1,436 households, respectively (National Institute

[1] Information obtained from municipal news (https://www.municipalidadosorno.cl/noticia.php?id=33237) and interviews with stakeholders, which are: Two professionals form Chilean Ministry of Environment, the head of Environmental Office of Municipality of Osorno, the president of a non-profit organization to environmental education in Osorno, two representatives of two neighbors board in Osorno and the chief of the main recycling company of the city. Interviews were held from July 2020 to August 2020.

of Statistics (INE), 2017). The selection criteria for these two neighborhoods were, firstly, that they were middle-income neighborhoods; secondly, that there were no existing recycling facilities (especially for plastics); and lastly, that the two areas were far from each other, which decreased the likelihood of spillover effects. Selection criteria also considered the technical capacity of the recycling company in charge of implementation. Appendix A shows the map of the city of Osorno and the location of both neighborhoods.

Our intervention was administered in three stages, and an intervention diagram, along with the timeline, is depicted in Appendix B. The first stage considered implementing a baseline scenario by providing fixed recycling infrastructure on the streets of the two selected neighborhoods. The procedure for the location followed the criteria generally used by the recycling company: places of easy access to the public (mainly squares and parks) and easy access for the company's trucks that must remove the material from the containers. In each neighborhood, a specific location of recycling fixed infrastructure followed a systematic procedure that considers the division of each neighborhood into smaller areas (i.e., polygons); thus, households were linked to a particular recycling station through these predetermined zones. These zones were defined using the Thiessen Polygons tool on ArcGIS, and both the treatment and control neighborhoods had nine polygons each, eighteen in total. The eighteen polygons considered around these stations in both treated and control neighborhoods are depicted in Appendix C. Regarding the type of recycling infrastructure, from the nine polygons in each neighborhood, one polygon had a mixed-material container (i.e., plastics, cardboard, glass) and the remaining eight had plastic bottle bins. Appendix D shows the type of recycling fixed infrastructure used in this study. At the beginning of this stage, households in both groups were provided with (plane) information about the availability of the fixed recycling system in their area through a door-to-door campaign, and every two months, this information was reinforced by posters on the streets, both in small neighborhood stores and at neighborhood bus stops. The baseline stage was carried out for eight months. In this period, we collected information on the amount of recovered plastic waste and the amount of waste incorrectly sorted, with a temporal frequency of two times per week. In the sixth month, a household survey was conducted to gather households' characteristics, household behavior concerning waste production and segregation, recycling decisions, households' perceptions of several pro-environmental behavior, among others.

The second stage consisted of implementing a door-to-door recycling collection service in the treatment neighborhood, while the control neighborhood remained with only fixed infrastructure. In this phase, there was mobile and fixed infrastructure simultaneously in the treatment group. The door-to-door service was provided once a week over six months, so the first and second stages were completed in fourteen months. At the beginning of this stage, households in the treatment group were provided with (plane) information about the availability of both fixed and mobile recycling infrastructure. Similarly, households in the control neighborhood were provided with the same information they were given during the first stage. Information was administered using the same protocol adopted in stage one. It is important to emphasize that the content of these messages was merely informative on the locations of recycling stations and which materials to recycle.

The third stage, starting from month fifteenth, consisted of an information campaign targeting households in the treated neighborhood, in addition to the door-to-door service implemented in the second stage. In this stage, both the door-to-door service and the information campaign were administered simultaneously. We provided normative information appealing to personal norms[2] through flyers to every household in the treatment neighborhood and by posting brochures at bus stops and grocery stores. In contrast, households in the control neighborhood were provided with the same (plane) information they were given in previous stages. Also, in both sectors, we visited the places where the signs were posted every two months, checking their conditions, and replacing them, if necessary. Appendix E presents the messaging timeline and the brochures with the plane and normative information. Finally, an ex-post survey was carried out at the end of this stage. We surveyed the same household from the first survey. The entire intervention took 91 weeks, from December 2020 to September 2022.

2.3. Data and Baseline Characteristics

Our design includes two sources of information: (*i*) records of the amount of recycled materials and the presence of non-sorted waste and (*ii*) household surveys. The first source of information was collected by the leading local recycling company, which measured the amount of material collected in kilograms at each infrastructure facility on the same days, two times per week (Tuesdays and Fridays), from each recycling bin and container installed in both neighborhoods. In the second and third stages of our intervention, this company also measured the amount of material collected by the truck that went door-to-door to pick up recycling materials. Because the company

[2] By distributing a brochure with illustrations and the phrase: "When I do not recycle or do not maintain the recycling infrastructure, it increases pollution in our neighborhood. Recycling is our compromise with the environment and a better future", we appeal to the personal responsibility into engage in recycling activities to take care of the environment and the future generations.

could only offer this free service on a weekly basis, and the containers were measured twice a week, the records of plastic collected by the truck (in kilograms) were divided into two periods following the weekly dynamics of withdrawals (i.e., the weekly percentage of collected kilograms on Tuesday and Friday, at the polygon level). Thus, there are two weekly data for the truck service. Considering twenty-one months of intervention (i.e., 91 weeks of collection) from 18 recycling stations, the total observations from the experiment are 3,276. We are interested in two outcome variables: (*i*) the total amount of recycled plastic materials at the polygon level and (*ii*) the amount of incorrectly sorted material present in the collected waste (non-recyclable waste) by polygon.

During the second year of implementation of the intervention, some neighbors complained about the misuse of the containers, forcing the company and the municipality to remove the mix-materials containers before the end of the intervention in both sectors.[3] This resolution required the removal of this infrastructure in weeks 54 and 84 in the treatment and control sectors, respectively. Moreover, a plastic bottle bin was installed in week 64 in the treatment sector, whilst, due to its closeness to the end of the intervention, no infrastructure was added in replacement in the control sector. The removal of the containers resulted in a loss of observations. To assess the sensitivity of estimated effects to the loss of observations in response to the removal of infrastructure, our empirical strategy proposes a procedure to overcome this problem.

The second source includes individual surveys to gather information on households' socioeconomic characteristics, recycling practices, and the pro-environmental behavior of a sample of households in the experimental area. An ex-ante survey was conducted at the end of the first stage of the intervention (i.e., six months after the fixed recycling infrastructure was installed as a baseline). We also conducted an ex-post survey at the end of the third stage of the intervention. The number of households surveyed in the first stage was 610, including 305 observations from the treatment neighborhood and 305 households from the control neighborhood. These figures were determined through random sampling in each neighborhood. For the ex-post survey, we interviewed 569 households, who were also being surveyed in the first survey.[4] In order to link households' characteristics and responses to recycling stations and polygons, we also collected data on coordinates to determine households' locations. We use information from the two surveys to analyze differences between sectors and understand potential effects mechanisms.

[3] These problems were reported in updated versions of the Pre-Analysis Plan (PAP) (Trujillo et al., 2023).
[4] Attrition occurred because some households refused to participate in the second survey, while others could not be located because they had moved.

A summary of the baseline characteristics of our outcomes of interest is presented in Table 1. Figures evidence the absence of statistically significant differences between treatment and control groups for each of the outcomes of interest at the baseline. This result holds when either considering the polygons with mixed material containers or only polygons with plastic bottle bins. In this period, the average amount of plastic collected per polygon and per removal was 7.18 and 6.84 kilograms for the treatment and the control sectors, respectively. When focusing solely on polygons containing bottle bins, no statistically significant difference was found (4.54 and 4.72 kilograms in the control and treatment sectors, respectively). Regarding the amount of unsorted waste, there was an average of 0.22 kilograms of unsorted waste per collection. Looking at the data only for the polygons with bottle receptacles, it can be seen that the average amount of unsorted waste is lower in both sectors, which confirms the community's complaints that more waste was deposited in the mixed receptacles than in the other type of infrastructure.

Table 2 displays the pre-treatment difference in means for socioeconomic and waste-related variables for both sectors using information from the ex-ante survey. There are no statistically significant differences between the control and treatment sectors. We asked respondents to declare the average weight of the waste bag they dispose of in the municipal landfill through the municipal truck service. The average self-reported[5] weekly per capita waste production is 5.99 kilograms in the control sector and 5.27 in the treatment sector. The percentage of households that declare to recycle is 71% in the control sector and 66% in the treatment sector. Using the geolocation of both surveyed households and recycling infrastructure is possible to observe that the average (Euclidian) distance from the household to recycling bins is 99.4 meters (i.e., approximately one block). Concerning socioeconomic characteristics, the average household size is about four members, and the monthly income, calculated as the sum of all household incomes, is US $1,181 and US $1,119 for the control and treatment sectors, respectively (given the exchange rate at the time). These figures show that both sectors are middle-income households in the Chilean setting. For respondents who were also household heads, the schooling level was, on average, 13 years; that is, they, on average, have the secondary education completed.

[5] Given the process of disposing of garbage, which involves taking out a garbage bag containing waste three times a week and handing it over to the municipal truck, there is currently no mechanism for households to accurately determine the weight of the garbage they produce. Consequently, individuals residing in these households are unaware of the precise amount of garbage generated. However, as each person is responsible for retrieving and placing the garbage bag outside their house, they can estimate its weight by gauging the force required to lift it. In order to mitigate potential bias arising from the absence of a standardized reference weight, we provided each respondent with a bag weighing one kilogram. This bag served as a reference point while considering their answer. The respondent's response was then multiplied by the number of times the household disposed of garbage and divided by the number of inhabitants in the household to derive a per capita measure.

Table 1. Pre-treatment Differences in Means of Outcome Variables

	All Polygons					Only polygons with plastic bottle bins				
	All	Control	Treatment	Diff.	p-value	All	Control	Treatment	Diff.	p-value
Recycled Plastic (Kg.)	7.18 (10.20)	6.85 (9.19)	7.52 (11.12)	0.68	0.227	4.63 (5.11)	4.54 (4.66)	4.73 (5.53)	0.19	0.533
Non-sorted waste (Kg.)	0.22 (1.68)	0.14 (1.44)	0.30 (1.88)	0.16	0.074	0.11 (1.13)	0.14 (1.51)	0.08 (0.53)	-0.06	0.354
No. Obs.	1332	666	666			1184	592	592		

Note: Own calculations based on the recycling company's weighing records. Standard deviations are in parentheses. Statistical inference is based on a two-sample t-test.

Table 2. Pre-treatment Differences in Means of Socioeconomic Characteristics and Waste-related Variables

	Mean Control	Mean Treatment	Difference in means	p-value	No. Obs. Control	No. Obs. Treatment
Waste production and recycling						
Per capita waste production (in kilograms/week)	5.99 (4.74)	5.27 (6.37)	-0.72	0.1164	301	303
Recycling practice (sort and dispose waste for recycling)	0.71 (0.46)	0.66 (0.48)	-0.05	0.180	301	303
Distance to the nearest recycling infrastructure (meters)	99.66 (46.82)	99.08 (45.25)	-0.58	0.877	301	303
Socio-economics characteristics						
Household size (number of members)	3.58 (1.37)	3.49 (1.21)	-0.09	0.411	301	303
Household income (US$/month)	1181,0 (663.58)	1118,9 (724.97)	-62,04	0.273	301	303
Household head's schooling (Years)	12.98 (3.62)	13.28 (3.19)	0.3	0.393	199	182

Note: own elaboration based on a first survey (ex-ante). Standard deviations are in parentheses. Statistical inference is based on a two-sample t-test. 1 US$ = 737,64 CLP (average value in survey period: 06-15-2021 to 07-09-2021). CLP refers to Chilean pesos.

2.4 Mechanisms of Effects

Our intervention was designed and implemented to assess the effects of the interactions between fixed and mobile recycling infrastructure on plastic recycling and waste sorting and to evaluate the extent to which the provision of normative information has the potential to reinforce/counteract these effects. Our hypothesis posits that introducing door-to-door recycling services could increase the total amount of plastic waste collected. This can be attributed to an increase in the availability of cost-efficient recycling options in the household (i.e., access to services reducing the effort and time needed for transporting waste to recycling containers) (Bernstad, 2014; Lee et al., 2017; Miafodzyeva & Brandt, 2013; Nainggolan et al., 2019; Sidique et al., 2010). Furthermore, we anticipate a decrease in the amount of plastic recycling collected through fixed infrastructure, suggesting a substitution effect between fixed and mobile recycling systems. We also expect an increase in non-sorted because of the rise in overall recycling activity. Regarding reinforcement effects of norm-based messaging, we hypothesized a positive effect of normative information provision (e.g., an increase in recycling in response to being aware of the message embedded in the information pamphlets).

Nevertheless, it could also be the case that appealing to personal norms may reduce the amount of waste generated by the household, and thus, the amount of recycling could either decrease or remain the same. However, some features of our experimental design prevent us from isolating the impact of information provision alone. Instead, our analysis focuses on providing norm-based information alongside the door-to-door recycling service. If personal norms effectively incentivize households to sort waste for recycling, we anticipate a further increase in the amount of plastic recycling. In such a scenario, the coefficient associated with the norm-based information treatment would be positive and more significant than the coefficient of the first treatment. The expected effects of the intervention are comprehensively depicted in our pre-analysis plan (Trujillo et al., 2023).

3. Empirical Strategy

The empirical strategy is based on reduced-form specifications. The estimate of interest is the Average Treatment Effect (ATE) in the polygons associated with each container or bin. The ATE is defined as $\alpha = E[y_{it1} - y_{it0}]$, where y_{it1} and y_{it0} are the potential outcomes for polygons regarding plastic waste recycled (in kilograms) and waste sorting before and after the intervention, respectively. We are interested in the following effects: (1) the effect of the curbside collection service on the disposal of plastic waste and on waste segregation quality and (2) the reinforcement effect of the personal norms messaging on disposal of plastic waste and waste segregation once curbside collection service came into effect. We are mainly focusing on two outcomes: the total amount of plastic recycled and the amount of non-recyclable waste. Because of the timeline of the intervention, we also propose evaluating the indirect effects of normative information provision. Such analysis allows us to assess a potential substitution/complementarity relationship between fixed and mobile recycling infrastructure. The main specification consists of the difference-in-differences estimator for each outcome of interest.

3.1 Total Plastic Recycling

$$rec_{it} = \beta_1 T_{1i} \times P_{1t} + \beta_2 P_{1t} + \beta_3 T_{2i} \times P_{2t} + \beta_4 P_{2t} + \ a_i + e_{it} \tag{1}$$

Where rec_{it} is the total amount of recycled waste measured in kilograms in the polygon i at the period t; T_{1i} is a treatment status indicator that equals 1 if the polygon belongs to the treatment group (mobile infrastructure) and 0 otherwise; P_{1t} is a post-treatment indicator that equals 1 if the period of observation is in the second stage and 0 otherwise; T_{2i} is a treatment status indicator that equals 1 if the sub-sector belongs to the treatment group (mobile infrastructure and messaging) and 0 otherwise; P_{2t} is a post-treatment indicator that equals 1 if the period of observation is in the third stage and 0 otherwise and a_i is a fixed effect by polygon. The coefficients of interests are β_1 and β_3. We expected a positive sign for both coefficients, with $\beta_3 > \beta_1$, revealing an increase in the total amount of material collected due to the mobile infrastructure and a reinforcement effect derived from information appealing to personal norms.

3.2 The Indirect Effect on Fixed Infrastructure

To assess the presence of a potential substitution/complementarity relationship between the type of infrastructure, we will also evaluate the effect of the curbside collection service on the amount collected by containers and bins; that is, we will subtract from the total amount that part that has been collected by the truck. To do that, we use the following specification:

$$rec\_cont_{it} = \alpha_1 T_{1i} \times P_{1t} + \alpha_2 P_{1t} + \alpha_3 T_{2i} \times P_{2t} + \alpha_4 P_{2t} + \ a_i + e_{it} \tag{2}$$

Where rec_con_{it} is the amount of recycled waste measured in kilograms in the polygon i only by the containers and bins at the period t; T_{1i} is a treatment status indicator that equals 1 if the polygon belongs to the treatment group (mobile infrastructure) and 0 otherwise; P_{1t} is a post-treatment indicator that equals 1 if the period of observation is in the second stage and 0 otherwise; T_{2i} is a treatment status indicator that equals 1 if the sub-sector belongs to the treatment group (mobile infrastructure and messaging) and 0 otherwise; P_{2t} is a post-treatment indicator that equals 1 if the period of observation is in the third stage and 0 otherwise and a_i is a fixed effect by polygon. The coefficients of interests are α_1 and α_3. We expected a negative sign for both coefficients, suggesting a substitution effect between fixed and mobile recycling systems. We expected that the substitution effect would be weaker once information appealing to personal norms is distributed, that is, $\alpha_3 < \alpha_1$ in absolute terms

3.3 Waste Sorting quality

$$waste_{it} = \delta_1 T_{1i} \times P_{1t} + \delta_2 P_{1t} + \delta_3 T_{2i} \times P_{2t} + \delta_4 P_{2t} + a_i + e_{it} \qquad (3)$$

Where $waste_{it}$ is the amount of incorrectly classified material present in the recollected waste (non-recyclable waste) measured in kilograms in the polygon i at the period t; T_{1i} is a treatment status indicator that equals 1 if the polygon belongs to the treatment group (mobile infrastructure) and 0 otherwise; P_{1t} is a post-treatment indicator that equals 1 if the period of observation is in the second stage and 0 otherwise; T_{1i} is a treatment status indicator that equals 1 if the sub-sector belongs to the treatment group (mobile infrastructure and messaging) and 0 otherwise; P_{2t} is a post-treatment indicator that equals 1 if the period of observation is in the third stage and 0 otherwise and a_i is a fixed effect by polygon. The coefficients of interests are δ_1 and δ_3. We expected a positive sign for both coefficients, informing of an increase in the percentage of incorrectly classified material due to the mobile infrastructure. We expected that this increase would be attenuated once information appealing to personal norms is distributed, that is, $\delta_3 < \delta_1$ in absolute terms.

As mentioned in Section 2, removing the containers resulted in a loss of observations. To overcome this problem, we carry out two estimation strategies. The first one is to estimate the effects of both treatments using the information from the polygons where there were only bins, i.e., we estimate using the information from 16 polygons, leaving out all the observations coming from the polygons with mixed containers. Considering twenty-one months of intervention (i.e., 91 weeks of collections) from 16 recycling stations, the total observation from the experiment is 2,912. The second strategy is to estimate the effect of the first treatment (door-to-door recycling service) with observations from all polygons but estimating only up to week 54, using this last estimation as a robustness test of the effect of the first treatment. For the three outcomes, we add withdrawal and payment day dummies to account for the effect of salary payments and the first day of the week the withdrawal takes place, i.e., Tuesdays. Because the treatment operates at the polygon level, we cluster the standard errors accordingly. Because there are less than 30 clusters, and the existing literature shows that when the number of clusters is small, the failure to control for within-cluster error correlation can lead to misleadingly small standard errors and large *t*-statistics and low *p*-values (Angrist & Pischke, 2008; Cameron & Miller, 2015), we apply the correction for the small number of clusters by using the wild cluster bootstrapping (Roodman et al., 2019) and report the corresponding *p*-values[6].

4. Results

We designed our intervention to investigate the effect of mobile facilities on plastic recycling and quality of sorting and assess the potential reinforcing effects of providing information appealing to personal norms. This section presents the results for the three outcomes of interest mentioned above. For the analysis, data is restricted to polygons with plastic bottle bins only (16 polygons) due to the problems commented on in sections 2 and 3[7].

4.1. Effects on Total Plastic Recycling

We begin by analyzing the direct effects of mobile recycling infrastructure and information treatments on plastic recycling. Estimates corresponding to the specification given by Equation (1) are summarized in Table 3. The first treatment intervention (door-to-door recycling service) has a positive and statistically significant effect on the amount of recycled plastic waste. Improving the options to recycle by providing a door-to-door recycling service increased the amount of plastic recycling collected per withdrawal and polygon, on average, by 3.5 kilograms, an increase of about 74% concerning plastic recycling in the control sector. The increase of 3.5 kilograms of plastic recycling, per polygon, per withdrawal is equivalent to approximately 58 plastic bottles (2-liter bottles), considering that, on average, 1 kilogram equals about 16 plastic bottles.[8]

Regarding the reinforcing effect of norm-based messaging (the second treatment arm), we find that the combined effect of mobile infrastructure with the provision of norm-based information has a positive and statistically significant effect on the amount of plastic waste recycled.[9] Specifically, it increases the amount of plastic waste recycled per polygon per withdrawal, on

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[6] The basic idea is to generate a large number of bootstrap samples that simulate the distribution from which the actual samples are drawn. Then, each bootstrap sample is used to compute the bootstrap test statistic using the same testing procedure as the original sample. The bootstrap p-value is then calculated as the proportion of the bootstrap statistic that is more extreme than the statistic in the original sample. For more details, see Roodman et al. (2019).

[7] We also estimate the effects of the first treatment for the three outcomes using data from all polygons (18 polygons), obtaining similar results presented in Appendix F.

[8] This equivalence was calculated from data collected in the field.

[9] Our design does not allow us to isolate the effect of messages alone. That is, what is being evaluated is a combined effect of the door-to-door recycling service along with normative messages, which is referred to as a reinforcement effect.

average, by 1.3 kilograms, an increase of 31.1% with respect to plastic recycling in the control sector. Like the previous result, this can be translated into approximately 21 plastic bottles per polygon per removal. Even though this effect is sizeable and statistically significant, the effect is smaller than adding only the door-to-door recycling service. Figure 1 shows the average weekly amounts of total recycled plastic in the pre-treatment and post-treatment periods for the control and treatment groups. It is possible to observe how the difference in the weekly average plastic recycling between groups changes over time. The difference between the control and treatment groups is more prominent in the period of treatment one, and this difference decreases in the period of the second treatment. Figure 2 displays the monthly evolution of the estimated ATEs during the treatment periods. It is shown that there is an immediate effect of the treatment. Plastic recycling increased, on average, by 2.9 kilograms in the second month following the experiment. From the third month onward, increases in plastic recycling are, on average, 3 kilograms. Monthly ATEs are statistically significant at the 5% level in all periods from the second month of the treatment onwards. Although there is a substantial effect over time, we also observed a decline in the impact during the third stage (second treatment). The literature has shown that the effects of interventions adjust over time (for example, Jaime Torres & Carlsson, 2018; Linder et al., 2018; Ling et al., 2023). Nevertheless, the treatment has had its most considerable effect in the summer months (January and February), a decline in March (when work and academic activities restart in Chile), and an adjustment in the following months.

It was expected that the norm-based messages would have a reinforcement effect on the impact of the door-to-door service. However, the results showed that providing norm-based messages when households already have access to door-to-door recycling services seems ineffective in strengthening the first treatment impact, as they had a positive but smaller effect compared to the door-to-door recycling service impact alone. This latter result can be attributed to two potential explanations. The first possibility is that the messages employed may not have the sufficient persuasive power to reinforce plastic recycling behaviors effectively. If this is the case, the positive effect of the second treatment, which involved providing door-to-door recycling service along with messages based on personal norms, is significant because the effect of providing door-to-door recycling service is larger and persists over time. Alternatively, the second explanation is that the messages have significantly influenced the reduction of plastic usage. Although our experimental design does not enable us to ascertain the predominant effect, the data obtained from the second survey can offer valuable insights to elucidate the findings[10].

Regarding the difference between the impacts of both treatments on the total amount of plastic recycling, it is observed that households in the treated sector were more aware of the door-to-door recycling service (first treatment arm) than of the messages (second treatment arm) because 50.4% of surveyed households declare to know about the door-to-door recycling service and only 13% affirm having seen or received the norm-based brochures. It is possible that the mode of delivering the messages through flyers to the households and posting signs at grocery stores and bus stops may not have been effective enough to get the attention of individuals. Concerning the effects over time, the highest treatment effects are in the summer months, possibly explained by increased consumption of beverages packaged in plastic bottles due to higher temperatures.

Our findings are consistent with those of Struk (2017), who found that curbside collection increases separation rates by 40% compared to drop-off sites, and those of Sidiqu et al. (2010), that also found that curbside recycling services and drop-off sites were effective in increasing the rate of recycling when implemented together. Results are also in line with those found by Best & Kneip, (2011); Dahlén & Lagerkvist, (2009) and Gradus, (2020). That is, as expected, as the options available for recycling increase, the amount of waste recycled also increases. Regarding the reinforcing effects of norm-based messages, our results might be in accordance with those found by Chong et al. (2015), who found that messaging was ineffective in increasing the recycling rate. This result suggests that one or two-shot information delivery is not sufficient for personals norm to evolve.

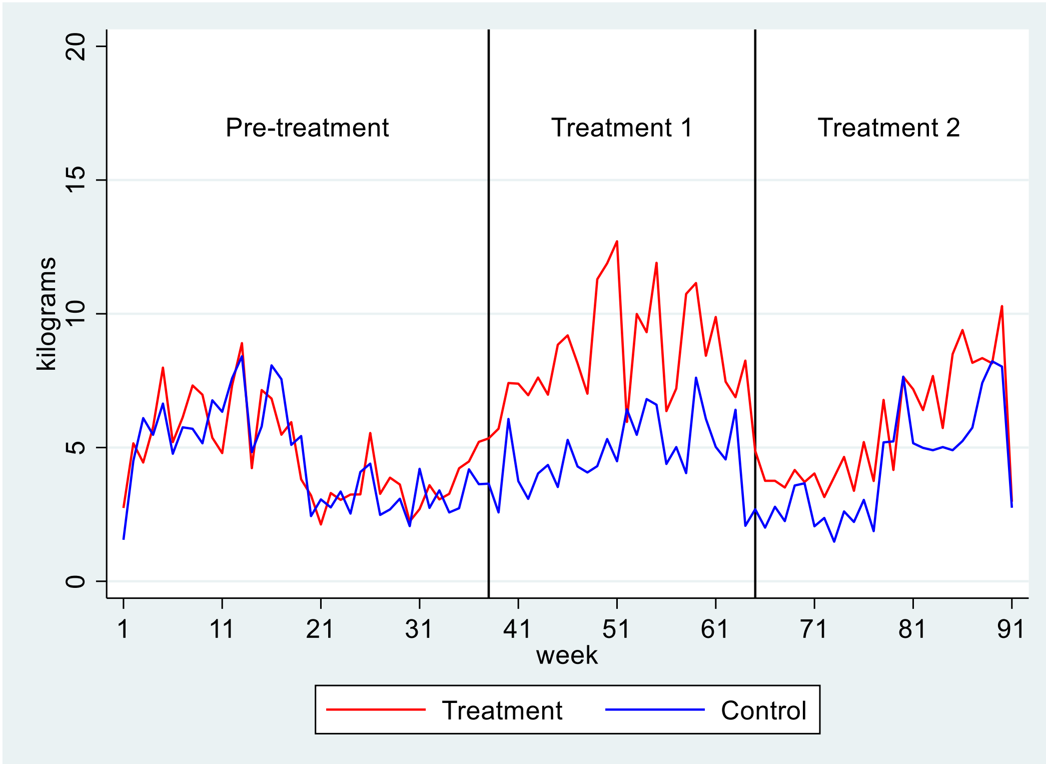
[10] Descriptive statistics of the closing survey are presented in Appendix G.

Table 3. Treatment Effects for Total Plastic Recycling

Variables	(1)	(2)	(3)	(4)
Treated1*Post1	3.545**	3.545**	3.545**	3.545**
	(1.323)	(1.328)	(1.328)	(1.328)
	[0.012]	[0.012]	[0.012]	[0.012]
Post-treatment1	0.250	-0.014	0.073	-1.494**
	(0.199)	(0.496)	(0.478)	(0.602)
	[0.279]	[0.985]	[0.864]	[0.023]
Treated2*Post2	1.301**	1.301**	1.301**	1.301**
	(0.515)	(0.517)	(0.517)	(0.517)
	[0.025]	[0.025]	[0.025]	[0.025]
Post-treatment2	-0.351	-1.414	-1.204	-3.057***
	(0.324)	(0.771)	(0.784)	(0.807)
	[0.301]	[0.100]	[0.164]	[0.000]
Constant	4.632***	3.488***	3.488***	2.126***
	(0.253)	(0.438)	(0.438)	(0.668)
Month-by-year	no	yes	yes	yes
First-half-of-the-month	no	no	yes	yes
Tuesday	no	no	no	yes
No. Obs	2912	2912	2912	2912
R-squared	0.054	0.134	0.134	0.210

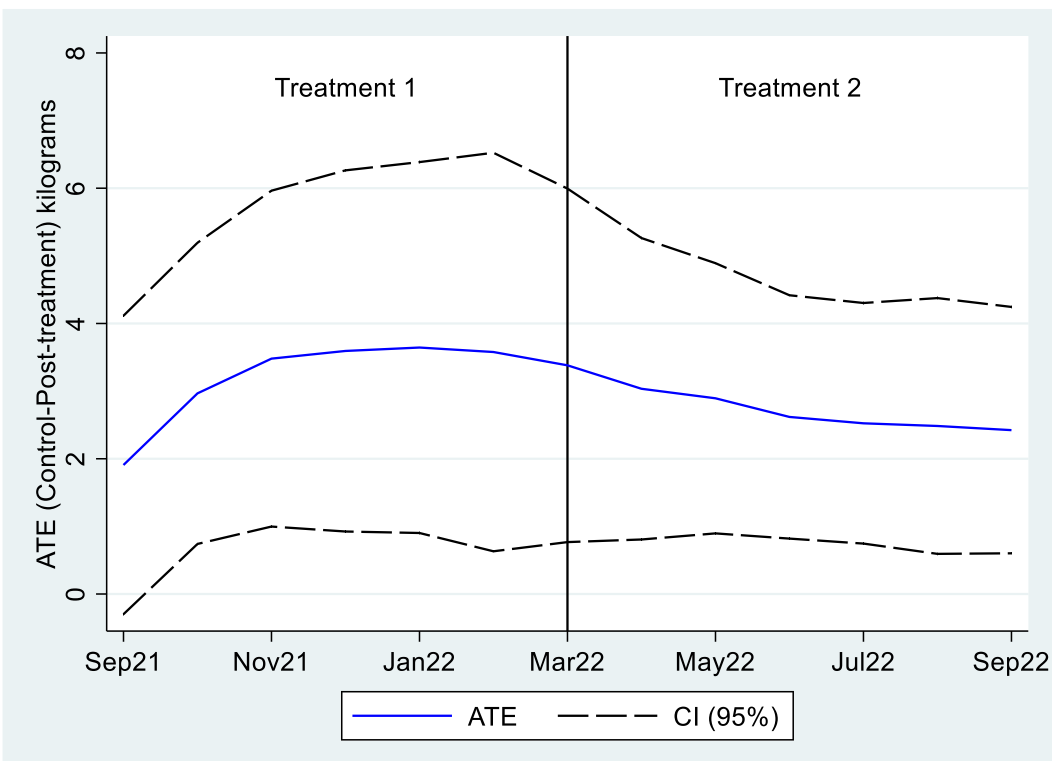
Notes: The dependent variable is recycled plastic per polygon per withdrawal, in kilograms. Clustered Standard errors in parentheses. Wild bootstrap cluster p-values in square brackets generated using boottest command in Stata 17 (Roodman et al., 2019) for standard errors clustered at the polygon level (16 clusters). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 1. Average Weekly Plastic Recycling Over Time (kgs/week)



Source: Own elaboration.

Figure 2. Monthly Average Treatment Effects Over Time



Source: Own elaboration.

4.2. Effects on Recycling in Fixed Infrastructure

Next, we look at the effects of both treatments on the use of fixed infrastructure. Results are presented in Table 4. We find evidence of a complementary relationship between both fixed and mobile recycling options, as the effect of adding a door-to-door recycling system to the existing fixed infrastructure is positive and statistically significant. As shown in Figure 3, we observe that the use of fixed infrastructure is increased, especially in the first treatment period. We do not observe households decreasing the use of fixed infrastructure for mobile service. On average, 82.6% of the plastic was disposed of in fixed infrastructure during the first treatment period; during the second treatment period, this average increased to 85.4%. It seems that both recycling options are complementarians instead of substitutes since it is observed that providing door-to-door service also increases the disposal of plastic waste in fixed infrastructure.

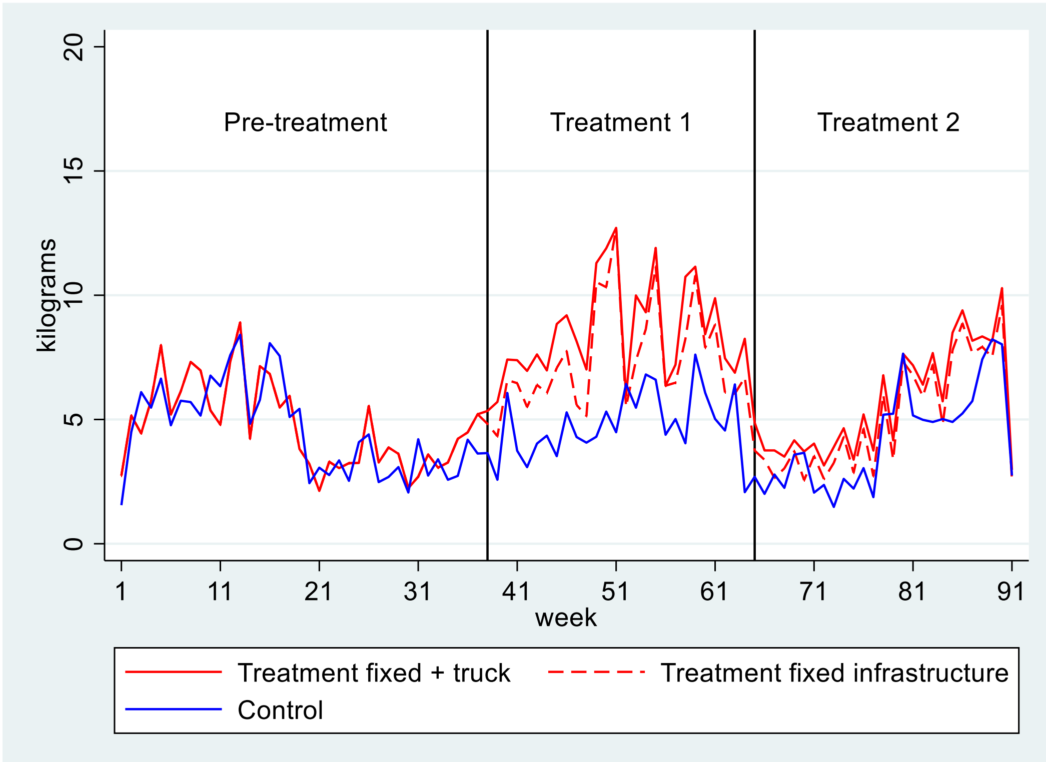
However, the complementary effect found in the first months is no longer significant in the coming months, suggesting that the norm-based message was not able to reinforce this primary effect. A possible explanation is that the door-to-door recycling service increased the amount of plastic recycling not only because it increased the recycling options but also because the truck passing in front of each house acted as a reminder of the possibility of sorting their waste for recycling. The closing survey reveals that even when households knew about the door-to-door recycling service, the most used system was the fixed infrastructure. Households keep recycling with containers, and few households changed exclusively to door-to-door recycling services.

Table 4. Treatment Effects for Plastic Recycled in Fixed Infrastructure (Substitution or Complementary Effects)

Variables	(1)	(2)	(3)	(4)
Treated1*Post1	2.409*	2.409*	2.409*	2.409*
	(1.314)	(1.318)	(1.319)	(1.319)
	[0.099]	[0.099]	[0.099]	[0.099]
Post-treatment1	0.250	0.112	0.221	-1.283**
	(0.199)	(0.457)	(0.437)	(0.569)
	[0.274]	[0.802]	[0.601]	[0.046]
Treated2*Post2	0.677	0.677	0.677	0.677
	(0.525)	(0.527)	(0.527)	(0.527)
	[0.214]	[0.214]	[0.214]	[0.214]
Post-treatment2	-0.351	-1.371*	-1.111	-2.889***
	(0.324)	(0.733)	(0.721)	(0.787)
	[0.302]	[0.086]	[0.151]	[0.000]
Constant	4.632***	3.488***	3.488***	2.180***
	(0.252)	(0.439)	(0.439)	(0.663)
Month-by-year	no	yes	yes	yes
First-half-of-the-month	no	no	yes	yes
Tuesday	no	no	no	yes
No. Obs	2912	2912	2912	2912
R-squared	0.031	0.117	0.118	0.191

Notes: The dependent variable is plastic recycled per polygon per withdrawal only in fixed infrastructure, in kilograms. Clustered Standard errors in parentheses. Wild bootstrap cluster p-values in square brackets generated using boottest command in Stata 17 (Roodman et al., 2019) for standard errors clustered at the polygon level (16 clusters). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 3. Average Weekly Plastic Recycling Over Time (kgs/week) by Type of Infrastructure



Source: Own elaboration.

4.3. Effects on waste sorting quality

We now examine the effects of both treatments on the share of non-sorted waste present in the recycling collection. Results are shown in Table 5. We find that the presence of the door-to-door service increases not only plastic recycling but also the amount of non-sorted waste in fixed infrastructure by 0.189 kilograms. However, this effect is no longer significant as door-to-door service is reinforced with the normative message. A downtrend effect of the intervention is also a possible explanation for this insignificant effect. Non-recyclable material was found most of the time in the containers and bins in the street, and it was generally organic waste and construction debris. That could be explained by the visibility of actions and the possibility of identifying households that do not sort their waste correctly. In the door-to-door recycling service, the household gave its waste directly to a person on the truck, who could identify how the materials needed to be correctly sorted. On the contrary, the disposal of containers and bins in the street was completely anonymous. This result is consistent with those found by Bucciol et al. (2019), whose findings show that unsorted waste production is lower when it is possible to identify the household that does not sort their waste. However, it does not hold when more than two households share the same bin, as in this study's case of the containers and bins.

Table 5. Treatment Effects for Non-recyclable Waste Present in Recycling Collection

Variables	(1)	(2)	(3)	(4)
Treated1*Post1	0.189**	0.189**	0.189**	0.189**
	(0.099)	(0.100)	(0.100)	(0.100)
	[0.029]	[0.029]	[0.029]	[0.029]
Post-treatment1	-0.097	-0.002	0.006	-0.011
	(0.095)	(0.100)	(0.095)	(0.090)
	[0.525]	[0.991]	[0.958]	[0.909]
Treated2*Post2	0.062	0.062	0.062	0.062
	(0.104)	(0.105)	(0.105)	(0.105)
	[0.727]	[0.727]	[0.727]	[0.727]
Post-treatment2	-0.076	0.068	0.087	0.067
	(0.102)	(0.208)	(0.200)	(0.194)
	[0.594]	[0.868]	[0.844]	[0.892]
Constant	0.112***	-0.000	-0.000	-0.015
	(0.030)	(0.037)	(0.037)	(0.039)
Month-by-year	no	yes	yes	yes
First-half-of-the-month	no	no	yes	yes
Tuesday	no	no	no	yes
No. Obs	2912	2912	2912	2912
R-squared	0.003	0.013	0.013	0.013

Notes: Dependent variable is the amount of non-sorted waste per polygon per withdrawal, in kilograms. Clustered Standard errors in parentheses. Wild bootstrap cluster p-values in square brackets generated using boottest command in Stata 17 (Roodman et al., 2019) for standard errors clustered at the polygon level (16 clusters). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5. Conclusions

Solid waste generation is increasing worldwide, driven by population growth, urbanization, and changing consumption patterns. Scalation in waste generation has significant environmental, social, and economic impacts. In response to this global issue, governments and organizations are implementing policies to promote sustainable waste management practices, such as recycling programs, to reduce the negative impacts of waste on the environment and human health. This paper analyzes the effects of adding door-to-door recycling services when a fixed recycling infrastructure is available and examines potential reinforcement effects resulting from norm-based information provision in two sectors of a Chilean city. Our results show that adding a door-to-door recycling service on top of a drop-off system increases plastic recycling, and both types of infrastructure seem to be complementarians. We also observe that norm-based messaging did not reinforce the effect on the amount of plastic recycling and that the combined effect of having both door-to-door collection and messaging is lower than providing door-to-door collection only. Moreover, results indicate that adding door-to-door recycling services increases the amount of non-recyclable waste collected.

This paper has several implications for recycling policy design. First, our results show that increasing recycling options and providing cost-effective recycling services for households increases the amount of waste recovered for recycling and household participation in waste recovery programs, which is consistent with the findings from previous literature. Second, the complementary relationship between door-to-door recycling services and open-access containers suggests that, despite the problems associated with the latter (e.g., contamination and collapse due to misuse and irregular collection), households value the availability of this type of infrastructure in their neighborhoods and appreciate its benefits, such as the possibility of disposing of waste at any time of day. Third, our results show that the provision of a curbside recycling service not only increased the amount of plastic recycled through the door-to-door collection but also increased the amount of plastic recycled through fixed infrastructure, suggesting that the presence of a truck collecting recyclables to each household may have served as a reminder of the opportunity to recycle. This result is consistent with other studies showing that people believe in the benefits of recycling but do not practice it regularly because it is not a habit. Reminding people that recycling is an available option can be essential to promoting behavioral change. Another important finding is that just as the amount of material disposed of for recycling increased due to the introduction of mobile recycling infrastructure, so did the presence of incorrectly sorted waste, mainly in containers on the street. Lastly, giving brochures with norms-based messages calling for responsibility and commitment to the environment by recycling once households already had door-to-door recycling had a lesser effect than only improving recycling services in their area. This can mainly be explained by the limited reach of these messages in households due to the messaging strategy using bus stops and neighborhood businesses. In this sense, in the design, dissemination, and long-term maintenance of recycling programs, communication and active involvement of neighborhood associations or organizations is fundamental and should be considered. It is necessary to know how involved and informed households are about what is happening in their neighborhoods.

Finally, our research presents various avenues for further investigation and extension. Three prominent directions for future exploration are worthy of mention: Firstly, a primary focus for extension is to isolate and examine the impact of norm-based messaging in order to assess its effectiveness in promoting recycling practices. This extension would provide valuable insights into the efficacy of this strategy and its ability to drive positive behavioral changes. Secondly, it would be worthwhile to investigate the relevance of information provision timing in fostering the development of personal norms and encouraging pro-environmental behaviors. This understanding will enable us to tailor our messaging to maximize its impact and increase the likelihood of sustainable actions. Lastly, enhancing the experimental design by incorporating elements that enable the evaluation of information's role as a potential trigger for changes in people's behavior, specifically concerning recycling practices and waste generation, would be a crucial step forward. By understanding how information influences behavior, we can devise more targeted interventions to drive sustainable actions. Exploring these avenues will not only advance scientific knowledge but also provide practical insights into developing effective strategies for promoting recycling and reducing waste.

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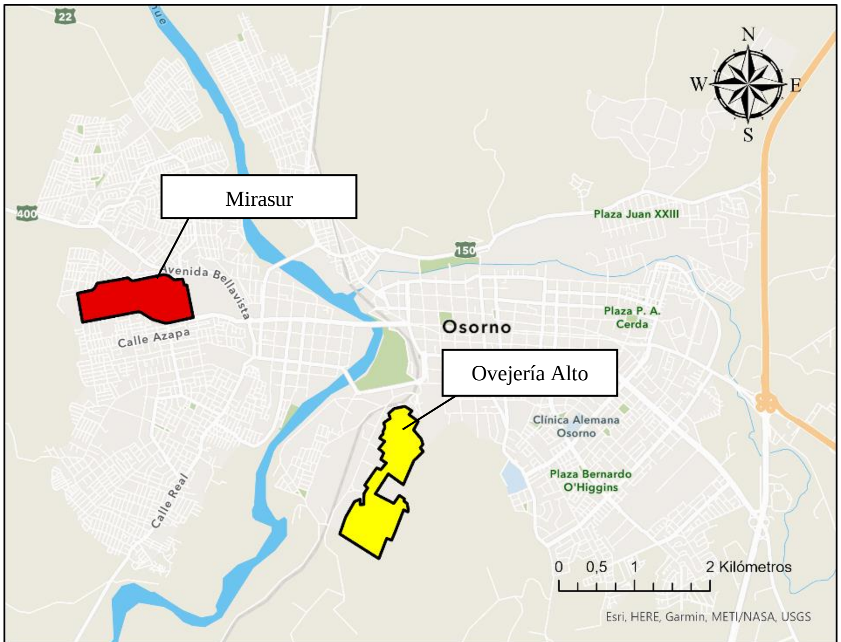
Appendix A. Osorno City, places of the intervention

Fig. A1. Osorno city places of the intervention



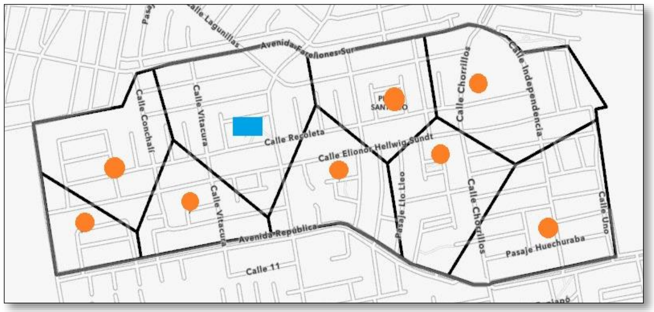
Source: Own elaboration

Appendix B. Intervention diagram and timeline

Figure B1. Intervention diagram

Stage 1: Baseline (Eight months)

a) Treatment: Mirasur



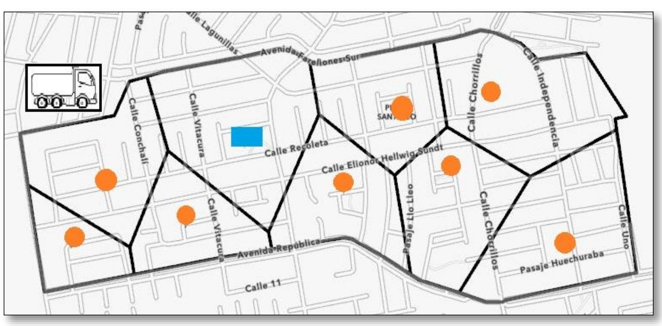
Recycling plastic bottles bin

Container of mixed materials

b) Control: Ovejería Alto

Stage 2: Curbside collection system (Six months)

c) Treatment: Mirasur

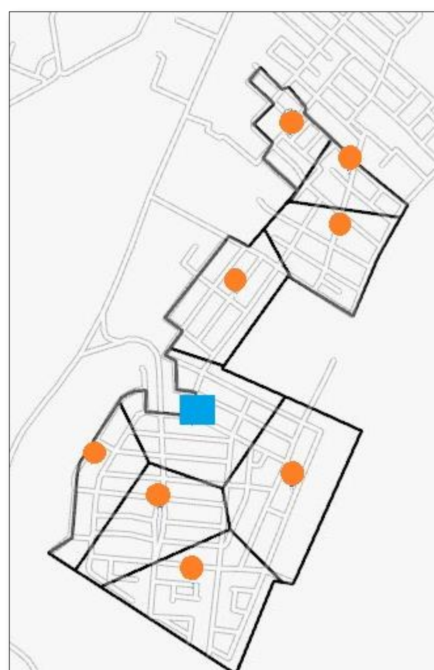


Recycling plastic bottles bin

Container of mixed materials

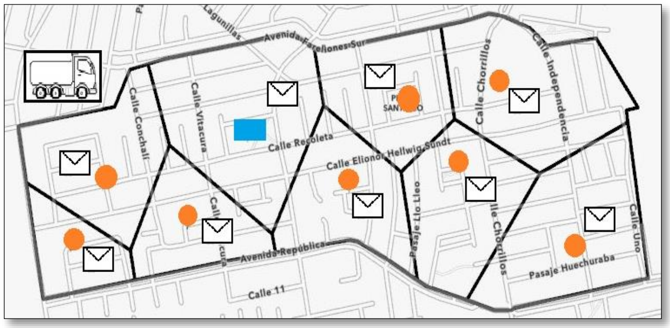
Truck to door-to-door collection service

d) Control: Ovejería Alto



Stage 3: Normative information (Six months)

e) Treatment: Mirasur



f) Control: Ovejería Alto

Recycling plastic bottles bin

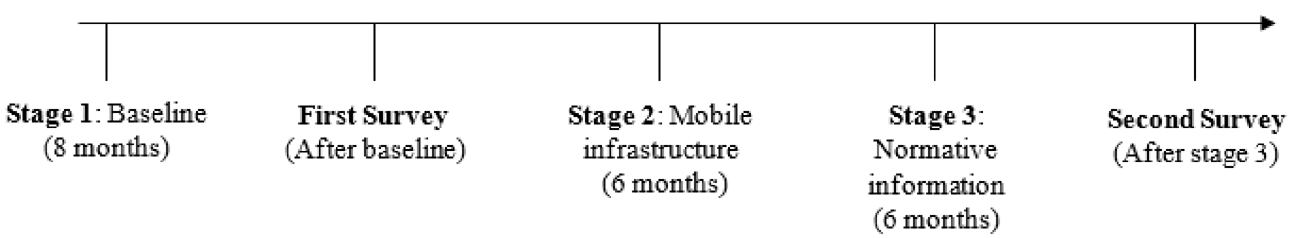
Container of mixed materials

Truck to door-to-door collection service

Delivery of normative information

Source: Own elaboration

Figure B2. Intervention timeline



Source: Own elaboration

Appendix C. Thiessen Polygons[11]

Thiessen Polygons is an ArcGIS tool used to divide the area covered by the input point features into Thiessen or proximal zones. These zones represent full areas where any location within the zone is closer to its associated input point than to any other input point. The theoretical background for creating Thiessen polygons is as follows:

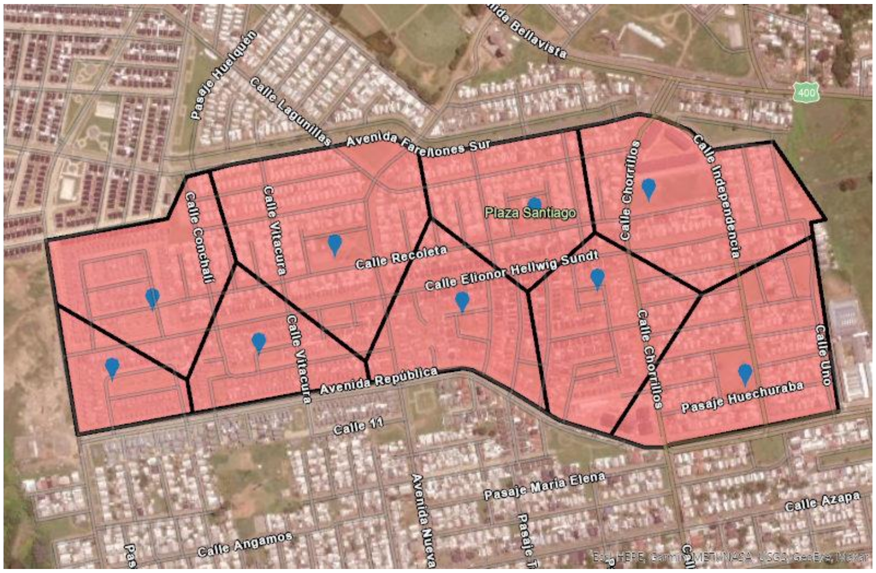
- Where *S* is a set of points in coordinate or Euclidean space (x,y), for any point *p* in that space, there is one point of *S* closest to *p*, except where point *p* is equidistant to two or more points of *S*.
- A single proximal polygon (Voronoi cell) is defined by all points *p* closest to a single point in *S*, that is, the total area in which all points *p* are closer to a given point in *S* than to any other point in *S*.

Thiessen proximal polygons are constructed as follows:

- All points are triangulated into a triangulated irregular network (TIN) that meets the Delaunay criterion.
- The perpendicular bisectors for each triangle edge are generated, forming the edges of the Thiessen polygons. The location at which the bisectors intersect determines the locations of the Thiessen polygon vertices.

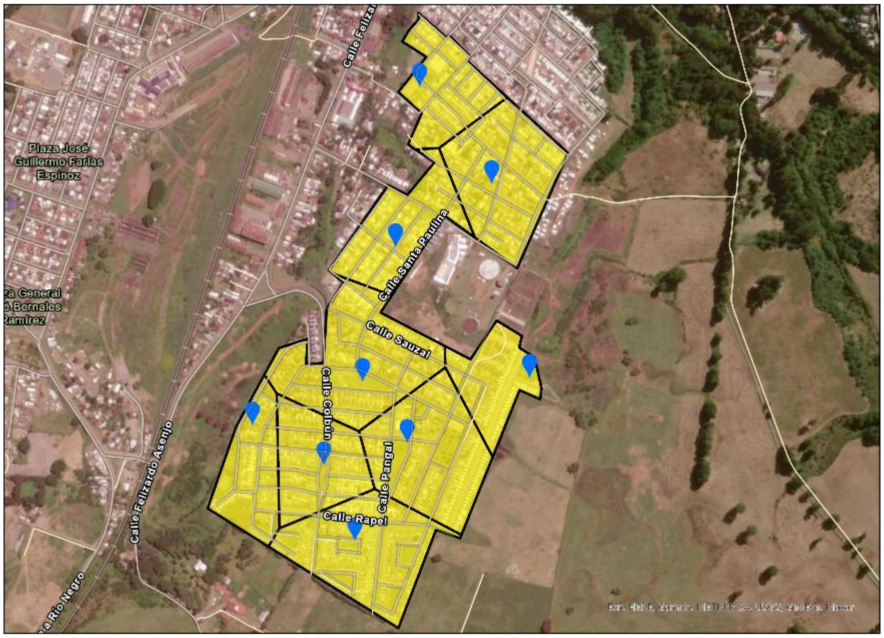
[11] Information obtained from: https://desktop.arcgis.com/en/arcmap/latest/tools/analysis-toolbox/create-thiessen-polygons.htm

Figure C1. Thiessen Polygons in Mirasur (treatment area)



Source: Own elaboration

Figure C2. Thiessen Polygons in Ovejería Alto (control area)



Source: Own elaboration

Appendix D. Fixed recycling infrastructure's characteristics

Figure D1. Recycling plastic bottles bin

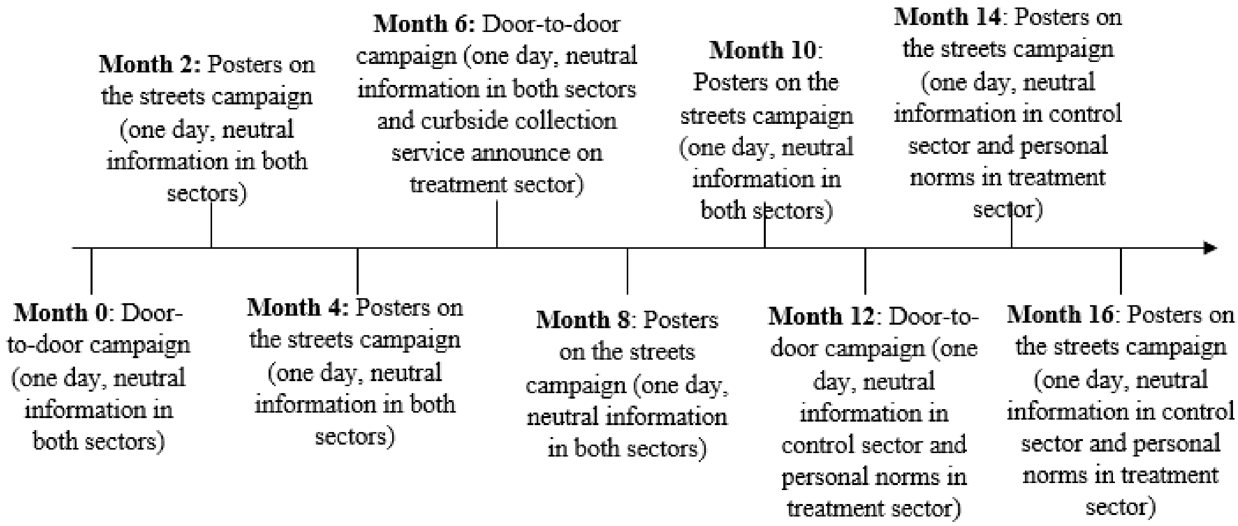
The recycling plastic bottles bin is a container of 1.80 meters high and 0.95 meters in diameter. The capacity is 1.28 m^3.

Figure D2. The container of mixed materials

The container of mixed materials is a receptacle with dimensions of 4 x 2 x 1.80 meters (length x width x height). It has different places in which materials are deposited (plastics, cardboard, glass, and cans). The capacity is 14.4 m^3.

Appendix E. Messaging timeline and brochures examples

Figure E1. Messaging timeline[12]



Source: Own elaboration

[12] The door-to-door campaign should be understood as the distribution to each home of a brochure announcing the start of the recycling program and what materials can be recycled. Due to COVID-19 pandemic conditions, we did not establish direct contact with households.

Figure E2. Brochure plane information example (in Spanish)

Figure E3. Brochure plane information example and door-to-door collection service announce, during stage 2, only treatment sector (in Spanish)

Figure E4. Brochure with normative message example, during stage 3, only treatment sector (in Spanish)

Translate: "When I do not recycle or do not maintain the recycling infrastructure, it increases pollution in our neighborhood. Recycling is our compromise with the environment and a better future".

Appendix F. Treatment effects of door-to-door recycling service with all polygons

Table F1. Treatment effects for total plastic recycling

Variables	(1)	(2)	(3)	(4)
Treated1*Post1	3.992*	3.992*	3.992*	3.992*
	(2.057)	(2.063)	(2.064)	(2.064)
	[0.074]	[0.074]	[0.074]	[0.074]
Post-treatment1	0.969	1.165	1.011	-1.752***
	(1.078)	(0.945)	(0.914)	(0.597)
	[0.702]	[0.280]	[0.326]	[0.004]
Constant	7.184***	4.882***	4.882***	2.455
	(0.310)	(1.118)	(1.118)	(1.752)
Month-by-year	no	yes	yes	yes
First-half-of-the-month	no	no	yes	yes
Tuesday	no	no	no	yes
No. Obs	1944	1944	1944	1944
R-squared	0.050	0.080	0.080	0.188

Notes: The dependent variable is plastic recycled per polygon per withdrawal in kilograms. Clustered Standard errors in parentheses. Wild bootstrap cluster p-values in square brackets generated using boottest command in Stata 17 (Roodman et al., 2019) for standard errors clustered at polygon level (18 clusters). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates include all polygons through week 54.

Table F2. Treatment effects for plastic recycled in fixed infrastructure (Substitution or complementary effect)

Variables	(1)	(2)	(3)	(4)
Treated1*Post1	2.775	2.775	2.775	2.775
	(2.084)	(2.090)	(2.091)	(2.092)
	[0.233]	[0.233]	[0.233]	[0.233]
Post-treatment1	0.969	1.370	1.225	-1.483**
	(1.078)	(0.943)	(0.910)	(0.583)
	[0.649]	[0.167]	[0.205]	[0.018]
Constant	7.184***	4.883***	4.883***	2.504
	(0.315)	(1.124)	(1.124)	(1.758)
Month-by-year	no	yes	yes	yes
First-half-of-the-month	no	no	yes	yes
Tuesday	no	no	no	yes
No. Obs	1944	1944	1944	1944
R-squared	0.030	0.060	0.061	0.167

Notes: The dependent variable is plastic recycled per polygon per withdrawal only in fixed infrastructure, in kilograms. Clustered Standard errors in parentheses. Wild bootstrap cluster p-values in square brackets generated using boottest command in Stata 17 (Roodman et al., 2019) for standard errors clustered at polygon level (18 clusters). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates include all polygons through week 54.

Table F3. Treatment effects for non-recyclable waste present in the collection

Variables	(1)	(2)	(3)	(4)
Treated1*Post1	0.204	0.204	0.204	0.204
	(0.140)	(0.140)	(0.140)	(0.141)
	[0.221]	[0.221]	[0.221]	[0.221]
Post-treatment1	-0.057	0.230	0.235	0.252
	(0.095)	(0.209)	(0.204)	(0.216)
	[0.628]	[0.345]	[0.321]	[0.266]
Constant	0.220***	-0.000	-0.000	0.015
	(0.021)	(0.129)	(0.129)	(0.115)
Month-by-year	no	yes	yes	yes
First-half-of-the-month	no	no	yes	yes
Tuesday	no	no	no	yes
No. Obs	1944	1944	1944	1944
R-squared	0.001	0.014	0.014	0.014

Notes: Dependent variable is the amount of non-sorted waste per polygon per withdrawal, in kilograms. Clustered Standard errors in parentheses. Wild bootstrap cluster p-values in square brackets generated using boottest command in Stata 17 (Roodman et al., 2019) for standard errors clustered at polygon level (16 clusters). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates include all polygons through week 54.

Appendix G. Descriptive Statistics closing survey

Table G1. Descriptive Statistics, closing survey in treatment sector

Variable	Mean	St. Dev.
Declare to know about the door-to-door recyling service (%)	0.50	0.50
Declare to know about the norm-based messages (%)	0.13	0.34
Recycle with door-to-door recycling service (%)	0.36	0.48
When recycling, most used recycling system: Fixed infrastructure (%)	0.75	0.44
When recycling, most used recycling system: Door-to-door service (%)	0.23	0.42
When recycling, most used recycling system: Other (%)	0.02	0.15
Declare to know about the norm-based messages (%)	0.13	0.34

Source: own elaboration based on second survey.