Zero Waste Cities

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Abstract

Reducing municipal waste is a challenge for urban policymakers around the world, but the best strategies for effective waste management are often not clear. We analyze to what extent participating in the *Zero Waste* Europe initiative can act as a commitment device for cities. Exploiting novel municipal-level waste data from Italy between 2010 and 2020 allows us to compare the trajectory of the 314 towns that joined the *Zero Waste* initiative at different points in time to a control group. We discuss the importance of socio-economic, geographical and institutional factors, as well as self-selection into the program. Our data set show the wide variation of municipal waste per capita levels across Italy. Our preliminary analysis suggests that membership in the *Zero Waste* program, in our sample period, does not yet lead to a decrease in a city's waste per capita level. However, we observe a significantly higher share of separately collected waste in *Zero Waste* cities which is both statistically and economically significant.

JEL Classification: Q53, Q58, O18, R50

Keywords: Municipal waste, program evaluation, separate collection, Environmental Kuznets Curve, waste management

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1 Introduction

With the effects of climate change visible all around the world, the need for mitigation and a sustainable use of resources becomes ever more evident. More and more economic actors are taking steps in the direction of a circular model, which is centered around sustainable products with minimal waste and whose materials keep circulating in the economy even after the products' lifetime; see Zaman (2015) for an overview. In particular, lower-level governments see room for this kind of improvement in their waste management systems.

Within Europe, the question of which waste management strategy to use recently became more important. As of 18 December 2020, the European Council, the European Commission, and the European Parliament announced, in a provisional[1]agreement, a more ambitious Emission Trading Scheme (ETS) including emissions from municipal incinerators in its scope among others (European Parliament, 2022). Municipalities now have an even greater incentive to make meaningful changes to their current waste management strategies in order to meet emissions reductions agreements.

The *Zero Waste* Europe (ZWE) initiative was founded in 2014 as the European regional branch of the Global Alliance for Incinerator Alternatives (GAIA). It addresses local communities and municipalities with a vision of sustainable systems, challenging them to 'rethink their relationship with resources and eliminate waste for the benefit of people and planet.' The wheels were set in motion in Italy back in 1997 when a local school teacher, Rosssano Ercolini, recognized that a planned incinerator build could potentially have negative impacts on residents and the environment (Henam and Sambyal, 2019). He was able to convince local residents and officials of the potential dangers of the incinerator plant and block the build in his community and beyond as nearby communities threatened with incinerators also joined the fight (Henam and Sambyal, 2019). From there the *Zero Waste* Italy movement began informally, in 2004, when facing the Naples waste management crisis, and expanded in 2007 when grassroots activists asked the mayor of Capannori to formally adopt the goals of zero waste and become the first *Zero Waste* city (Zero Waste Italy, 2021b). In 2013, *Zero Waste* Italy took its current shape as a non-profit organization and joined the network of ZWE. This network, which started with a few interested *Zero Waste* partners has now grown substantially and, as of 1 January 2022, encompassed 450 municipalities in 28 European countries (McQuibban, 2022). Municipalities that join the initiative commit to reducing their municipal waste so that natural resources are conserved and overall environmental impact is reduced. Yet, there is notable flexibility in the precise measures to be implemented to allow for each city's particular conditions and goals. If *Zero Waste* Candidate cities want to become certified,

[1]Starting in 2024, EU countries must measure, report, and verify emissions from municipal waste incineration plants. The EU Commission will present a report by 31 January 2026, discussing the goal of including these plant emissions in the EU ETS from 2028 with a possible opt-out until 2030 at the latest (European Parliament, 2022).

the criteria include successfully implementing a plan to reduce municipal waste to some established threshold or beyond, conducting multiple waste analyses to better understand areas of improvement, increasing the amount of collected and recycled municipal solid waste (MSW), collecting data on waste generation and recycling as well as the economic and societal impacts of the *Zero Waste* plan, implementing a program for organic waste management, and establishing a *Zero Waste* Advisory Board among others.

This combination of soft criteria and self-set goals with the self-selection into the *Zero Waste* Initiative brings up the question of how effective participation actually is. With cultural values and neighborhood effects playing a key role in waste management (Agovino et al., 2019, Bonan et al., 2021), membership in the *Zero Waste* Europe initiative sends a strong signal in terms of public communication. On the other hand, such a green label might also conceivably lend itself to exploitation by local politicians to benefit from a greenwashing effect while only taking mild steps towards sustainability (Li and van't Veld, 2015).

So the question is by how much do *Zero Waste* cities really reduce their overall municipal waste and increase their recycling rates compared to similar cities that have not joined the initiative? Does joining the *Zero Waste* program really act as a commitment device for cities struggling with their municipal waste? Is it mainly the efficient cities that are self-selecting into the program or even those that hope to gain from a greenwashing effect? As the *Zero Waste* Initiative gains prominence throughout Europe, evaluating the causal effect of membership becomes even more important for policymakers and the general public. To date, such a study is still missing.

We intend to fill this gap. Exploiting novel Italian municipal-level waste data between 2010 and 2020 allows us to compare the trajectory of the 314 towns that joined the ZWE initiative at different points in time to a control group. We discuss the importance of socio-economic, geographical and institutional factors, as well as self-selection into the program.

Our preliminary results suggest that joining the *Zero Waste* initiative is not yet associated with a decrease in municipal waste per capita in our sample period. Yet, there are stark differences in the share of separate collection, which is *ceteris paribus* 2.9-4.6 percentage points higher for *Zero Waste* cities than for others.

In addition to providing recommendations for municipal waste management, our insights hold lessons for other initiatives from the environmental realm and beyond. For example, Millard-Ball (2012) argues that joining climate action plans in California is not causal for cities' environmental management because voter preferences both push cities to opt into the plans and to implement the measures. Other studies have highlighted the long time period for environmental programs to take effect, as well as the overestimation of the effect by eager early adopters (Allcott, 2015).

The remainder of this paper is organized as follows: In Section 2, we anchor our study in the environmental economics literature. Section 3 presents the main pillars of the *Zero Waste Europe* initiative whose effectiveness we analyze. Section 4 gives insights on the data we use and its descriptive statistics. In Section 5, we present and interpret the results of our econometric regressions. Section 6 concludes.

2 Relation to the existing literature

By analyzing the effectiveness of the *Zero Waste Europe* initiative, we relate to the existing urban, environmental, and economics literature in several ways.

First, we add to the studies on waste management in cities. There are many city-level papers that evaluate individual waste management policies, often using difference-in-difference methods and/or synthetic control methods. Examples include Alacevich et al. (2021), who work with Swedish household data to analyze the staggered introduction of home-based organic waste sorting bins in the municipality of Partille, identifying a monthly waste reduction of 8%. Also, Bueno and Valente (2019) evaluate the impact of the introduction of Unit Pricing Systems for waste in the Italian city of Trento in 2013, finding that it decreased unsorted waste by 37.5%, mostly driven by waste avoidance and also by more recycling. Gautier and Salem (2023) exploit panel data on waste from 262 municipalities in Wallonia, Belgium, to show that households have a larger price sensitivity for residual than for organic waste. Pfister and Mathys (2022) study the introduction of a tax on unsorted waste in the Swiss canton of Vaud, using the neighboring cantons of Geneva and Valais as controls. They find a decrease of yearly unsorted household-waste by about 47 kg, which is about one fourth.

Within waste reduction policy measures, the strand of the literature on *Zero Waste* strategies in particular is also expanding; see Zaman (2015) for an overview. Ma et al. (2023) classify urban waste management approaches toward achieving *Zero Waste* in sixteen Chinese cities, underlining the global appeal of the topic. There are numerous case studies of particular *Zero Waste* measures in individual cities, such as Castigliego et al. (2021) who show that in Boston, the implementation of *Zero Waste* strategies have reduced the combustion of plastics and biomass in waste-to-energy combustion facilities and their associated GHG emissions. Yet, despite this growing literature on *Zero Waste* measures, there is no analysis of the effectiveness of membership in the *Zero Waste* initiative, let alone one with robust econometric methods.

More broadly, we also contribute to the literature on the outcome effectiveness of self-selected environmental plans and programs. A growing number of economic actors, be they cities or countries, are pledging to reduce emissions or commit to other sustainability goals. Yet, studies are only beginning to examine if such self-chosen goals or programs can actually be causal for success, or if success rates are driven by self-selecting into the program. For example, Millard-Ball (2012) provides a quantitative assessment of climate action plans that municipalities in California have set themselves. While cities with climate action plans have implemented more strategies to reduce emissions than cities without these plans (e.g. more green buildings and bicycle infrastructure), he concludes that the climate action plans do not play a causal role. He argues that citizens' preferences seem to be the driver behind both the self-selection into the plans and implementing measures to reduce emissions. In a similar vein, Allcott (2015) calls for caution in evaluating the effectiveness of energy conservation programs in the U.S. He finds that results from first adopters overstate the overall effectiveness because of their concentration in the most environmentalist-friendly areas. At the same time, environmental values can be fostered and promoted by public communication and priming as well as neighborhood influence. This has been shown, among others, by Agovino et al. (2019) on separate waste collection and Bonan et al. (2021) on household energy conservation. Joining the *Zero Waste Europe* initiative also carries a strong signaling effect. It has the potential to educate the public and add to the formation of pro-environmental behavior - unless it is either exploited as greenwashing for political reasons or only implements what environmentally-conscious voters would have demanded anyway. Analyzing the outcome thus carries insights for the design of environmental policy in a general way.

To the best of our knowledge, no study has yet examined the outcome of participating in such a large-scale waste reduction program as the *Zero Waste Europe* initiative, using panel data from thousands of municipalities and discussing both the waste per capita reduction outcomes and the self-selection effects.

3 *Zero Waste* Europe

What does the concept of zero waste mean exactly? Its concept encompasses more than increased recycling and composting as waste management strategies. At its core, zero waste refers to the conservation of resources throughout the entire life cycle of a product - from raw material sourcing to production to disposal (Thampapillai and Ruth, 2019). That withstanding, conscious energy consumption and efficient manufacturing also have their place within the zero waste framework. Beyond that, zero waste is said to be "achieved" when a value-added recovery system is in place and waste incineration and burial are eliminated. Taking a page from nature's playbook, the zero waste philosophy seeks to create ecosystemic relations to preserve value and energy through a circular economy.

Zero Waste Europe has applied this code along with the vision of the first European *Zero Waste* City, Capannori Italy, to the ZWE network, which now comprises over 480 municipalities throughout 15 different European countries. At the time of its founding as the European regional branch of the Global Alliance for Incinerator Alternatives (GAIA), *Zero Waste Europe* sought to foster the zero waste transition by creating the legislative, financial, and cooperative groundwork necessary to do so. The organization maintains a substantial EU-wide network of local and national NGOs with common objectives towards a zero waste future[2]. This bottom-up approach, together with the ZWE idea of thinking and acting "Glocaly" and the *Zero Waste* International Alliance, led to the creation of the *Zero Waste* commitment for municipalities. Cities signed on as *Zero Waste*rs through a commitment letter[3]to ZWE promising to align their goals with those defining the "*Zero Waste* City" and to continually seek to further reduce residual waste. See Figure 1 for a detailed overview of the commitment the ZWCs pledged, keeping in mind that specific goals were set by individual municipalities at their time of commitment.

Figure 1 – Flow chart of action points for becoming a ZWC

With their base in Brussels, ZWE plays a role in European legislation and is considered the top-down counterpart to the ZWC/MiZA grassroots initiatives. *Zero Waste Europe* brings perspectives from their work in local communities to create EU policy while also distributing EU-level visions back to local entities. The organization engages regularly in EU policy. For example, ZWE vied for the exclusion of waste incineration from the

[2]At present, also including their own subsidiary, Mission Zero Academy (MiZA) which acts as a local liaison for sharing upstream and downstream zero waste solutions, resources, and information. Together with MiZA, ZWE created a ZWC two-fold fee-based certification in place since 2021.

[3]With the letter campaign, enforcement and accountability were hard to monitor and maintain. This combined with the lack of set guidelines led to the current fee-based ZWE/MiZA Certification.

EU Taxonomy Regulation, the European Regional Development Fund and Cohesion Fund (worth €242.9bn), and the Just Transition Fund (worth €17.5bn) and won, even including investments in Material Recovery and Biological Treatment (MRBT) facilities (Zero Waste Europe, 2021).[4]

Hence, the goal of *Zero Waste Europe* is to to tackle waste at every level. Our task is to measure, in a large-scale study, whether efforts to do so at the local level have been successful and, if so, to what extent this success is a result of participating in the *Zero Waste* Cities program.

4 Data and Descriptive Statistics

We evaluate 314 Italian municipalities who have committed to the *Zero Waste* Cities regime and are in the process of obtaining their *Zero Waste* Cities Certification over an 11-year period, from 2010 through 2020. Our analysis focuses on Italian municipalities due to the established presence of ZWE in the country, the sheer number of adopters, and the fact that the first ever *Zero Waste* City was established in Capannori in the region of Tuscany in 2007. As of 1 January 2022, there were 462 cities enrolled in the program Europe wide, with more than 325 located in Italy, over 90 in Spain, and the remainder spread throughout Croatia, Slovenia, Romania, Ukraine, Germany, Belgium, Latvia, Bulgaria, and the UK (McQuibban, 2022). Figure 2 shows the spread of municipalities pledged to the *Zero Waste* strategy across Italy.

Given the move towards a circular economy, the legislative changes regarding waste management in Europe, and the expansion of ZWC candidates in the last 10 years, it is all the more important to evaluate the possible successes of the ZWC regime.

4.1 Data Sources and Data Overview

We combine data from various sources (see Appendix A for an overview) to construct our municipality-level panel dataset. Basic geographic and economic statistics are collected from Eurostat, the European Union's platform providing national statistics for EU member states and European Economic Area (EEA) countries and Switzerland, using their administrative NUTS classifications at cardinal (NUTS1), regional (NUTS2), and provincial (NUTS3) levels (Eurostat, 2020). Data on municipal area is taken from the Italian National Institute of Statistics (ISTAT), the producer of official statistics in Italy, among them population and economic censuses, social, economic, and environmental

[4] In addition to calling for an end to waste incineration, ZWE pushed to exclude Waste-to-Energy practices from the scope of the EU Taxonomy Regulation in favor of the MRBT approach. Other examples of their engagement in policy for the EU include working with the Food Policy Coalition to advocate for tall-order food-waste prevention measures, influencing the EU Single-Use Plastics Directive, and re-imagining all EU packaging to be recyclable and recycled by 2030 (Zero Waste Europe, 2021).

surveys, and more (I.Stat, 2010).

In order to conduct this study, municipal-level waste data and *Zero Waste* Classification information is necessary. Waste data is provided by ISPRA, the Higher Institute for Protection and Environmental Research (*Istituto Superiore per la Protezione e la Ricerca Ambientale*) in cooperation with the National System for Environmental Protection (*Sistema Nazionale per la Protezione dell'Ambiente*) and includes information on organic waste share, share separately collected, residual waste, and most major recycling categories (ISPRA, 2023). And finally, data on the zero-waste classification for Italian municipalities is provided by *Zero Waste* Europe [5](Zero Waste Europe, 2022). Data pertaining to the year of commitment by municipalities to make the transition to *Zero Waste* is collected using the Wayback Machine with the Zero Waste Europe (2022) and Zero Waste Italy (2021a) websites.

The current unbalanced panel dataset contains 88,246 observations for roughly 7,920 municipalities in Italy from 2010 until the end 2020. There are 312 municipalities who enter into the treatment group at staggered times, with the remaining municipalities contained in the control group.[6] Table 1 provides a short breakdown of the number of municipalities committing to the ZWC regime per year.

Table 1 – Year of Commitment

	Year	n
	2010	5
	2011	17
	2012	51
	2013	47
	2014	86
	2015	12
	2016	10
	2017	11
	2018	38
	2019	29
	2020	8
Total		314

Our main variable of interest is the amount of municipal waste per capita. In contrast to total municipal waste in tonnes, this allows us to abstract from the size of the city which runs from 29 inhabitants in Moncenisio to 2,873,494 inhabitants in Rome. Additionally, we consider the share of separate collection as another outcome variable. This means that certain types of waste, in particular organic, paper, glass and plastic are sorted and collected independently from residual waste.

[5]We are grateful to Jack McQuibban, Head of Local *Zero Waste* Implementation, from *Zero Waste* Europe for the data and expertise provided.

[6]Prior to 2010, two cities had committed to the ZWC regime and are included in the analysis as treated cities in 2010.

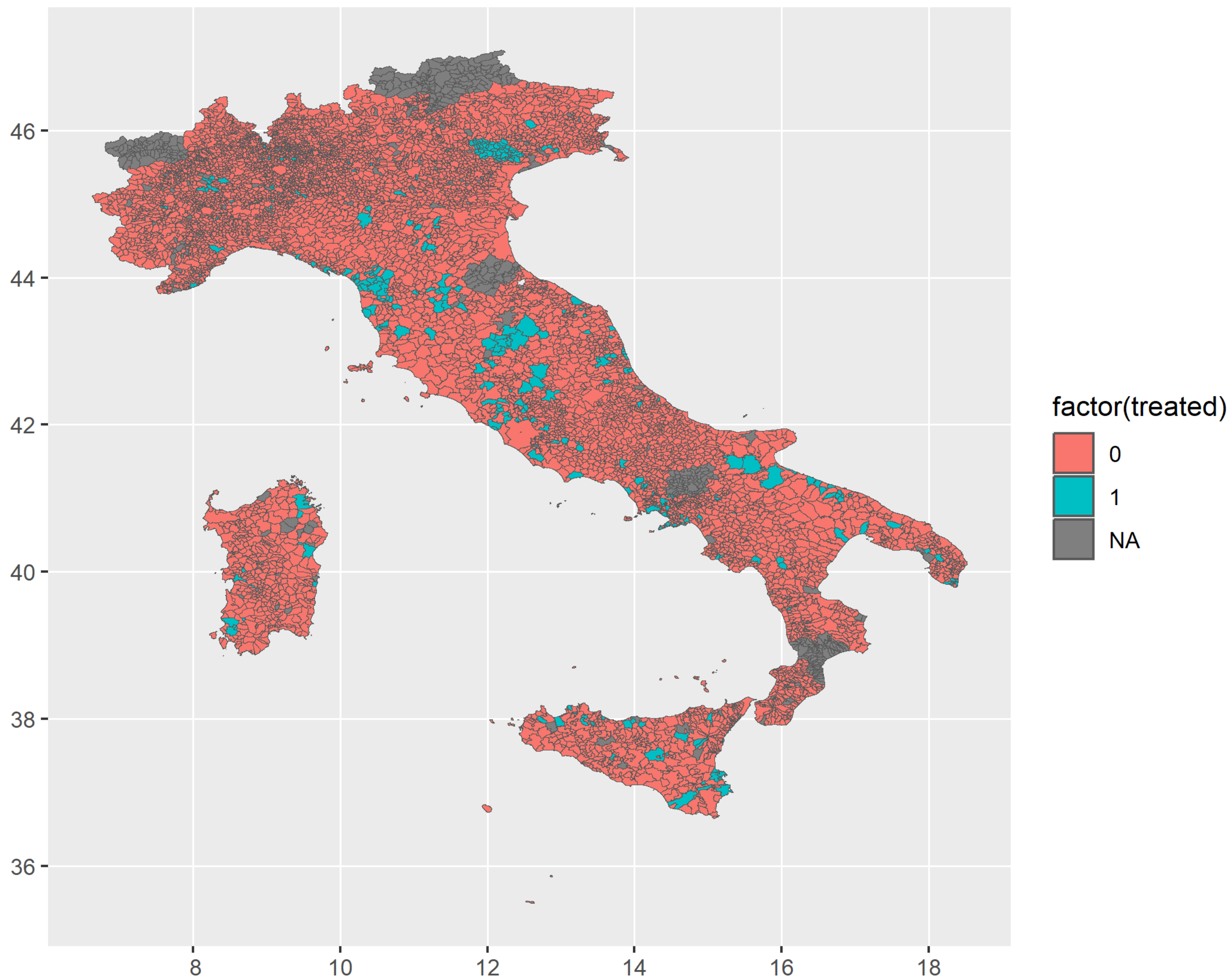


Figure 2 – Italian municipalities by treatment status

In Table 2, a geographic breakdown is presented for the spread of treatment and control cities, population, and waste per capita. We note that the treated cities are distributed across all the regions of the country, which is also visible from Figure 2. A particularly large number is located in the central part of the country, where the initiative was founded and where waste per capita is below the country average.

Table 2 – City Spread

Region	Treated Cities	Control Cities	Population	Per Capita Waste (kg)
Northeast	62	1,329	11,578,583	716.09
	(19.75)	(17.47)	(19.53)	(19.31)
Northwest	38	2,962	15,878,257	1,583.08
	(12.10)	(38.94)	(26.79)	(42.70)
Central	105	867	11,756,207	455.08
	(33.44)	(11.40)	(19.83)	(12.27)
South	75	1,709	13,616,140	661.75
	(23.89)	(22.47)	(22.97)	(17.85)
Insular	34	739	6,445,413	291.70
	(10.83)	(9.72)	(10.87)	(7.88)
N	314	7606	59,274,600	3,707.70

Note: The respective share of treated and control cities, population, and waste per capita (in kgs) in a given region are in parentheses. The control cities make up all other (non-treated) cities in the region. Distribution of treated cities based on commitments by 2020. Population and Per Capita Waste spreads based on 2020 values.

4.2 Control Variables

For our econometric analysis of whether the treated cities have a lower waste per capita and/or a higher share of separately collected waste than those in the control group, we consider a number of control variables. These include in particular a municipality's population, area, population density, regional dummies and demographic information, in particular education, share of working class and elderly population[7], and migration into and out of municipalities. GDP per capita is not available at the municipal level but at the provincial level (NUTS3) and is used to capture overall economic activity as well as prosperity. We also include environmental factors which capture the risk of flooding and landslides as well as changes in temperature.

Preliminary summary statistics in Table 3 show that the treated and non-treated municipalities have an average similar GDP per capita value, but the treated ones tend to be considerably more populous and denser. This makes it important to keep accounting for these characteristics in our econometric analysis. In terms of the outcome variable, the waste per capita values look very similar across the two groups, with 0.45 tons (treated) only slightly below 0.47 tons. A t-test for equality in means between the ZWCs and the control cities shows that the difference is not statistically significant at any conventional level of confidence. On the other hand, the share of waste that is separately collected is much higher in the treatment group (63.27%) than in the control group (52.61%).

[7]The working class in Italy is made up of those aged 15-62 years. The elderly population captures all residents aged 63 years and older.

Table 3 – Summary Statistics by treatment status

Treatment Status	0		1	
Variable	N	Mean	N	Mean
Waste per capita (tons)	82263	0.47	1982	0.45
Share Separately Collected	81928	52.61%	1982	63.27%
Organic Waste (tons)	55437	352.47	1683	686.57
Paper (tons)	80036	413.56	1969	1204.03
Glass (tons)	79335	241.96	1950	700.69
Plastic (tons)	78841	145.90	1954	467.49
Separately Collected	81928	1827.76	1982	6010.60
Population	86244	7137.63	2002	22952.71
Area	82717	36.76	1953	56.72
PopDensity	82717	297.02	1953	615.60
GDP	85554	26728.03	1992	25860.34
Regional Spread	86244		2002	
... CENTRAL	10215	12%	616	31%
... INSULAR	8241	10%	201	10%
... NORTHEAST	15456	18%	430	21%
... NORTHWEST	33199	38%	224	11%
... SOUTH	19133	22%	531	27%
MGMT cost per cap (unsorted)	31915	57.72	857	57.47
MGMT cost per cap (separated)	35587	41.16	1034	56.31
Heating degree days temp. sum	82127	2006.12	1970	1532.34
Cooling degree days temp. sum	82127	218.35	1970	288.24
Share with Higher Edu.	14505	0.079%	610	0.079%
Share of Working Pop.	13732	60%	520	61%
Share of Elderly Pop.	14198	29%	541	26%
Share Migrating In	52453	0.29%	804	0.18%
Share Migrating Out	52453	0.28%	804	0.16%
Low flood hazard area (sq km)	78529	4.23	1913	6.59
Medium flood hazard area (sq km)	81234	3.18	1966	4.79
High flood hazard area (sq km)	79149	1.57	1916	2.43
Moderate landslide hazard area (sq km)	81234	1.58	1966	4.05
Medium landslide hazard area (sq km)	81234	1.62	1966	2.26
High landslide hazard area (sq km)	81234	1.98	1966	2.74
Very High landslide hazard area (sq km)	81234	1.15	1966	0.70

Note: Summary statistics reported for control and treatment cities. Cities treated during the time from 2010-2020 are included in both groups depending on treatment status in that year (e.g. Riposto pledged to be a ZWC in 2014. They are therefore considered a control city through 2013, and thereafter, a treatment city). Heating and cooling degree days refer to the annual cumulative temperature difference between 18° and the mean temp. Temps below 18° are heating degree days and temps above, cooling. Indicative of energy use to cool and heat the home.

According to the t-test, this difference is statistically significant at the 1% level. This is why we will both look at waste per capita and at the share of separate collection in our analysis, where we use the staggered treatment.

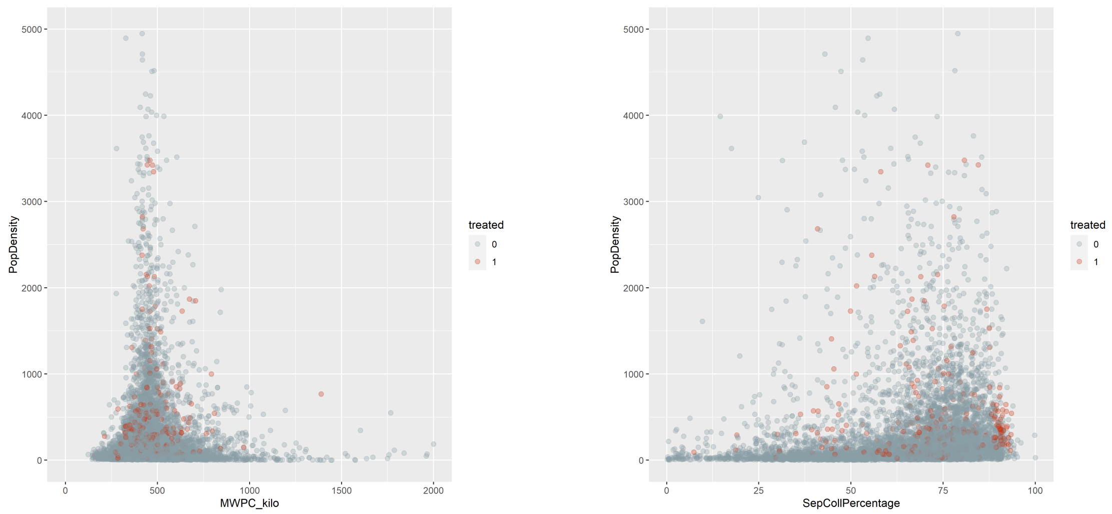
Another insight from the summary statistics can be gleaned from the hydrogeological risk factors (flood and landslide). At first glance, the treated cities seem to have, on average, greater areas impacted by these weather events. Testing for equality in means between our two city classifications tells us that these differences are significantly different across the board at the 1% level. This might suggest that these cities feel the effects of climate change more strongly and therefore become more environmentally conscious, thereby changing behaviors related to waste.

4.3 Correlations

Municipal waste per capita (annual) shows a wide variation across our units of observation, ranging from 26.82 kg in Lubriano (Viterbo) to 39,631.46 kg in Bard[8](Aosta). Let us examine its association with population density (Figure 3b). As the left scatter plot shows, a given waste per capita level can go in line with a range of possible population densities, this is small or large cities. Yet, both the lowest and highest values of waste per capita are reached in low-density municipalities, with most (big) cities having some intermediate waste per capita levels. Similarly, the separate collection rates in the right panel exhibit some positive correlation with population density. More densely populated places tend to have higher separate collection rates despite the wide variation. There is a cluster of *Zero Waste* cities at the high end of the separate collection rate distribution, at intermediate population density levels.

Another interesting relationship to explore is the one between waste per capita and income. In general, if a negative environmental externality or resource use first increases and then decreases with income, it is said to follow an Environmental Kurznets Curve (EKC), see Schmalensee et al. (1998) for early evidence of an EKC in CO2 emissions at the country level and Castells-Quintana et al. (2021) at the city level. Conceptually, the scale, composition, and technology effects are assumed to be behind such a shape, with the former dominating at earlier and the latter at later stages of economic development (Stern, 2004). The peak is often interpreted as decoupling of economic activity from environmental outcomes; yet, its existence and location varies widely across studies (Kacprzyk and Kuchta, 2020). This holds in particular when the economic outcome is not CO2 emissions but municipal waste. Yılmaz (2020) summarizes the ambiguous empirical literature on the existence of a Municipal Waste Kuznets Curve and find different results

[8]It is noteworthy that Bard is a small village with a large ratio of waste per capita likely due to the large amounts of tourism there. In future versions of this paper, we plan to account for tourism. Tourism has been found to play a role in explaining municipal waste amount and efficiency (in particular because of the seasonality of tourism, see Caponi (2022) on tourism and waste in Tuscany).



(a) Municipal waste per cap (kg) **(b)** separate collection rates

Figure 3 – Scatter plots showing the relationship between amount of waste or rate of separate collection and population density, respectively

for different OECD countries.

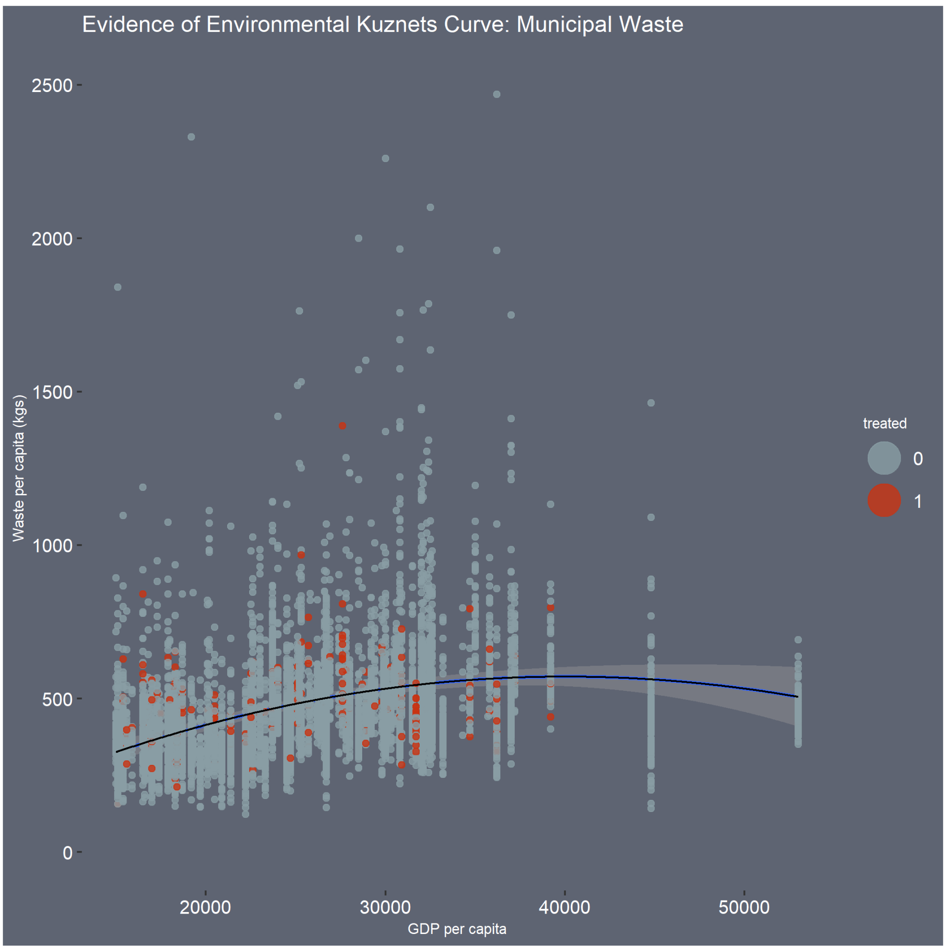


Figure 4 – Graphical representation of the relationship between GDP and municipal waste per capita in 2020

With our municipal-level waste per capita data and GDP per capita (at the provincial level), we investigate this relation both graphically and with a regression analysis. The mathematical expression can be written as

$$MWPC = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \epsilon, \quad (1)$$

where MWPC (municipal waste per capita) can be thought of as the level of environmental damage, GDP represents the current level of per capita output, and ϵ is the unobservable residual. α is constant, and β_1 and β_2, to be estimated, reflect the influences of income level on environmental quality. The EKC hypothesis postures, $\beta_1 > 0$ and $\beta_2 < 0$. The scatter plot in Figure 4 shows a rather wide variation of waste per capita values for a given income level. As one might expect, the waste values of the treated cities are less likely to be among the highest, but they can be below or above the average. The best-fit quadratic curve shows indeed a concave shape, albeit a very flat one. With nearly all cities in the sample having yet to reach the peak, there is little evidence of decoupling.

These insights are confirmed, when regressing waste per capita on GDP per capita and its square in various specifications; see Table 4. In the cross-sectional OLS regression (column 1), the statistical significance of the GDP per capita terms and their signs points towards an inverse U-shaped function. Unlike Chen (2010) in his sample of developing countries, we do not find evidence of an N-shaped curve (column 2). But the results are also dependent on the sample composition, as we note, when excluding Lombardia, the richest region (column 3). We furthermore do not find any statistically significant effect when using panel rather than cross-sectional data (column 4). We conclude that we do find some evidence for the existence of a municipal waste Environmental Kuznets Curve for the Italian cities, but its overall magnitude is vague and most cities are still away from a possible decoupling stage between income and waste. This makes it all the more interesting to examine if being a *Zero Waste* city can contribute towards such a development by leading to a reduction in waste.

5 Econometric Regressions

To determine the impact of membership in the *Zero Waste* initiative on waste per capita and separate collection rates, we start out by running the panel data regressions

$$Outcome_{it} = ZeroWaste_{it} + Controls_{it} + \alpha_i + \alpha_t + \epsilon it, \quad (2)$$

where the outcome is either municipal waste per capita or the separate collection rate in municipality i at time t, $ZeroWaste_{it}$ is indicator variable which takes the value of 1

Table 4 – Relationship between Municipal Waste Per Capita and Income

	Dependent variable:			
	Municipal waste per capita (kilo)			
	Cross-Section	N-Shape Curve	Cross w/out Lombardia	Panel Fixed Effects
	(1)	(2)	(3)	(4)
GDP (per cap)	0.028***	−0.054**	−0.011	−0.006
	(0.004)	(0.024)	(0.011)	(0.010)
GDP Squared	−0.00000***	0.00000***	0.00000**	
	(0.00000)	(0.00000)	(0.00000)	
GDP Cubed		−0.000***		
		(0.000)		
Reduced GDP Sqd				0.001
				(0.002)
Population Density	−0.009	−0.006	0.008	−0.003
	(0.011)	(0.011)	(0.014)	(0.051)
Treated (dummy)	−5.259	−7.210	−13.027	−13.186
	(33.803)	(33.783)	(37.929)	(32.853)
Constant	−11.712	747.943***	424.064***	
	(63.545)	(228.536)	(129.909)	
Observations	7,416	7,416	5,954	80,213
R^2	0.015	0.016	0.019	0.00001

*p<0.1; **p<0.05; ***p<0.01

Note: Different specifications to check for evidence of an EKC shown above. We regress municipal waste per capita on GDP and GDP^2 on 1) a 2020 cross-section, 3) a 2020 cross-section excluding the wealthiest region, and 4) a full panel from 2010-2020 with country and year fixed effects. In spec 2) we include GDP^3 to check for an N-shaped EKC using 2020 cross-sectional data.

if municipality i had joined *Zero Waste Europe* by time t and 0 otherwise, and α_i and α_t capture respectively, the municipality and year fixed effects. The numerous control variables include both socio-economic and geographical variables.

Regression results for both outcome specifications can be seen in Tables 5 and 6 for municipal waste per capita and separate collection rates respectively. In line with our statistical evaluation, our regression analysis suggests there is no statistically significant impact of the treatment status on the amount of waste per capita. The picture looks different for separate collection rates, however. In all three specifications of our model, all other things being equal, the expected rate of separate collection for *Zero Waste* candidate cities is 2.9-4.6 percentage points higher than for control cities, which is significant to the 1% level in our highest performing specification. We have to keep in mind that our time horizon of 10 years is rather short and treatment was staggered across that time. So it appears plausible that joining *Zero Waste* leads to more immediate changes in separate collection rates, which might take more time to materialize as a decrease in municipal waste levels. We include a number of controls in our regression as well, most of which are statistically significant as expected. Across both outcome designations we see that, *ceteris paribus*, a 1% increase in GDP corresponds to an increase in per capita municipal waste between 0.1457 kg and 1.939 kg. Per capita waste as well as separate collection rates also increase as population density increases, with a one unit increase in population density being associated with an additional of 0.009 - 0.010 kgs of waste per capita, or 0.001 percentage points more separate collection. One explanation could be that cities, which are more densely populated and also richer than rural areas, are likely to have more waste per capita. Thanks to more public resources and shorter ways for waste collection, their separate collection rates might be higher. We see that the *Zero Waste* treatment indicator matters in addition to these factors. In all of our regressions, shares of migration into and out of municipalities, the share of those with some studies, and a number of hydrogeological risk factors are also controlled for.

Our panel data regressions do not take the issue of endogeneity and program self-selection into account. In future versions of this paper, we are going to create treatment and control groups based on similar socio-economic characteristics of municipalities prior to *Zero Waste* membership. With the staggered difference-in-difference (DiD) method by Callaway and Sant'Anna (2021), we are planning to obtain more robust results to complement our preliminary findings. We additionally consider the machine-learning algorithmic generalized synthetic control (GSC) approach from Xu (2017), bypassing the parallel trends assumption of causal inference and instead using high-confidence uncertainty estimates. This quasi-experimental methodology synthetically produces counterfactuals for treated units by combining interactive fixed-effects and synthetic control models and employing a latent factor approach to minimize the mean squared prediction error — it semiparametrically estimates the individual treatment effect on each

Table 5 – Initial Panel Regression Specifications for municipal waste per capita

	Dependent variable:		
	Municipal waste per cap. (kg)		
	Pooled OLS	Provincial FE	Random Effects
	(1)	(2)	(3)
Treatment Status	14.458	−4.744	12.820
	(16.799)	(16.834)	(22.022)
lg(GDP)	193.856***	6.455	143.114***
	(21.728)	(183.075)	(25.455)
Pop. Density	0.009**	0.001	0.010**
	(0.004)	(0.005)	(0.005)
Higher Ed. Share	−2,208.750***	4,449.550	−547.092
	(747.555)	(7,353.577)	(908.717)
Share of Migration (into)	−31,503.590***	−18,728.120	−23,614.770***
	(6,619.767)	(54,754.840)	(8,521.485)
Share of Migration (out of)	28,154.490***	14,500.500	20,580.980**
	(6,241.281)	(55,480.120)	(8,040.090)
Low Flood Risk Area (sq km)	0.557	−0.547	0.817
	(0.811)	(0.894)	(1.086)
Med. Flood Risk Area (sq km)	0.653	1.954	0.798
	(2.182)	(2.226)	(2.938)
High Flood Risk Area (sq km)	3.972*	3.407	3.554
	(2.355)	(2.359)	(3.170)
Principal Attention Area (sq km)	−3.962***	−2.483***	−4.016***
	(0.598)	(0.638)	(0.805)
Moderate Landslide Risk Area (sq km)	0.500	0.350	0.441
	(1.009)	(1.048)	(1.356)
Med. Landslide Risk Area (sq km)	0.536	−3.286***	0.499
	(0.989)	(1.118)	(1.322)
High Landslide Risk Area (sq km)	−1.564*	0.707	−1.699
	(0.905)	(0.956)	(1.211)
Very High Landslide Risk Area (sq km)	5.350***	7.378***	5.203***
	(1.081)	(1.100)	(1.455)
Heating Degree Days (cum. annual temp.)	0.017*	0.070	0.018*
	(0.009)	(0.060)	(0.011)
Cooling Degree Days (cum. annual temp.)	−0.040	0.044	−0.088**
	(0.043)	(0.129)	(0.038)
Constant	−1,355.482***	−38.925	−961.831***
	(182.035)	(2,066.830)	(210.978)
Observations	9,191	9,191	9,191
R^2	0.066	0.103	0.040
Adjusted R^2	0.064	0.096	0.039
F Statistic	40.486*** (df = 16; 9174)	15.587*** (df = 67; 9123)	342.014***

*p<0.1; **p<0.05; ***p<0.01

Note: 2010-2020 panel regression outputs of municipal waste per capita on treatment status for 3 initial specifications: pooled OLS, provincial-level fixed effects, and random effects.

Table 6 – Initial Panel Regression Specifications for separate collections rates

	Dependent variable:		
	Rate of Separate Collection		
	Pooled OLS	Provincial FE	Random Effects
	(1)	(2)	(3)
Treatment Status	2.910**	4.631***	3.511**
	(1.175)	(1.028)	(1.516)
lg(GDP)	29.919***	−36.129***	14.568***
	(1.523)	(11.211)	(1.578)
Pop. Density	0.001***	0.001*	0.001***
	(0.0003)	(0.0003)	(0.0004)
Higher Ed. Share	−122.607**	−912.629**	139.087**
	(52.460)	(451.062)	(57.662)
Share of Migration (into)	−7,078.127***	−4,781.414	−6,829.193***
	(468.300)	(3,359.472)	(576.757)
Share of Migration (out of)	6,160.518***	7,477.188**	6,060.756***
	(441.584)	(3,407.071)	(545.076)
Low Flood Risk Area (sq km)	0.376***	0.129**	0.489***
	(0.057)	(0.055)	(0.078)
Med. Flood Risk Area (sq km)	−0.440***	−0.053	−0.472**
	(0.153)	(0.136)	(0.213)
High Flood Risk Area (sq km)	0.087	−0.051	0.019
	(0.165)	(0.144)	(0.229)
Principal Attention Area (sq km)	0.427***	0.186***	0.410***
	(0.042)	(0.039)	(0.058)
Moderate Landslide Risk Area (sq km)	0.129*	−0.081	0.123
	(0.071)	(0.064)	(0.098)
Med. Landslide Risk Area (sq km)	−0.294***	0.113*	−0.349***
	(0.069)	(0.068)	(0.096)
High Landslide Risk Area (sq km)	0.080	−0.143**	0.048
	(0.063)	(0.058)	(0.088)
Very High Landslide Risk Area (sq km)	−0.357***	−0.533***	−0.405***
	(0.076)	(0.067)	(0.105)
Heating Degree Days (cum. Temp.)	−0.006***	−0.004	−0.007***
	(0.001)	(0.004)	(0.001)
Cooling Degree Days (cum. Temp.)	−0.012***	−0.020***	−0.032***
	(0.003)	(0.008)	(0.002)
Constant	−212.834***	481.301***	−72.966***
	(12.760)	(126.683)	(13.469)
Observations	9,151	9,151	9,151
R^2	0.140	0.371	0.098
Adjusted R^2	0.138	0.366	0.096
F Statistic	92.634*** (df = 16; 9134)	79.867*** (df = 67; 9083)	980.281***

*p<0.1; **p<0.05; ***p<0.01

Note: 2010-2020 panel regression outputs of separate collection rate on treatment status for 3 initial specifications: pooled OLS, provincial-level fixed effects, and random effects.

treated unit (Xu, 2017).

6 Conclusion

We study membership of cities in the *Zero Waste Europe* initiative and its impact on municipal waste per capita as well as shares of separate collection. Assessing the causal impact of membership in the *Zero Waste* initiative becomes an increasingly important subject as city planners and urban policymakers seek to reduce municipal waste and move towards a more sustainable circular model in the face of climate change and resource scarcity. An additional driver of the shift away from incineration comes from the new European Emission Trading Scheme provisional directive that calls for the inclusion of emissions from municipal waste incineration from 2024 on (European Parliament, 2022). Data on Italian municipal-level waste management combined with information on membership into the *Zero Waste* Initiative from 2010-2020, allows us to examine the success of waste reduction and separate collection by *Zero Waste* member cities using sophisticated econometric analyses. Summary statistics show the wide range of municipal waste per capita and its non-trivial associations with population density and income. Our preliminary regression results suggest that membership in the *Zero Waste* program does not yet lead to a decrease in the municipality's waste per capita level in our sample period. On the other hand, separate collection shares are significantly higher in *Zero Waste* cities than in municipalities without this status, with the effect being 3 to 5 percentage points, when controlling for socio-economic and geographic factors. One interpretation of these results is that *Zero Waste* cities are investing in different waste management systems that rely on separate collection but whose effects on overall waste levels might not yet be visible within the first years that are at our disposal. While the initiative has not yet had a widespread impact on waste generation, it is contributing positively to improving recycling. Our findings provide important lessons for similar initiatives and programs while at the same time allowing for the further study of the subject employing more advanced econometric techniques. It is essential that governments, businesses, and society as a whole develop awareness and commitment to environmentally friendly practices to enable long-term positive change. Only through such collaborative efforts can we successfully address the challenges of climate change and create a livable world for future generations.

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A Appendix: Data Summary

Table 7 – Data Summary

Variable	Unit	Definition	Data Source
Area	Total area (km2)		Istat
Education	thousands	Amount of regional residents with some higher education	
Working Pop./ Elderly Pop.	Actual count	Number of residents in given municipality of working age or elder, respectively	
Migratory Patterns	Actual count	Inward and outward migrations for each region	
Hydrogeological Risk Factors	8 specifications: sq km	Low/med./high flood hazard area, Moderate/med./high/very high landslide hazard area, Pricipal Attention Area	
NUTS1		Geographical Region	Eurostat
Region (NUTS 2)		State Region	
Province (NUTS3)		Provincial Region	
GDP	Euro per inhabitant	Value by province	
Heating Degree Days and Cooling Degree Days	annual cumulative temp. (c) difference on heating and cooling degree days, respectively	weather-based indices capturing energy requirements in terms of heating and cooling buildings	
Population	Actual count		Catasto Rifiuti Sezione Nazionale, ISPRA- Istituto Superiore per la Protezione e la Ricerca Ambientale, Sistema Nazionale per la Protezione dell'Ambiente
Organic Waste	tons		
Paper	tons		
Glass	tons		
Plastic	tons		
Separate Collection Total	tons		
Municipal Waste Total	tons		
Separate Collection Percentage	percent		
MGMT cost (unsorted)	Municipal management costs per capita expressed in (Euro/ inhabitant*year)		
MGMT cost (separated)	Municipal management costs per capita expressed in (Euro/ inhabitant*year)		
Classification		3 specifications: ZW City, ZW Certified City, ZW Candidate City	*Zero Waste* Europe/ *Zero Waste* Italy
Year_comm	Year	Year of commitment to ZW regime	