

ESSAYS ON WASTE GENERATION

Ráti József

Doctoral School of Economics, Business and Informatics

Supervisor:

Bakó Barna, PhD

© Ráti József

Corvinus University of Budapest

Doctoral School of Economics, Business and Informatics

ESSAYS ON WASTE GENERATION

PhD Dissertation

Ráti József

Budapest, 2025

Contents

List of Figures	8
List of Tables	9
Acknowledgments	11
Introduction	12
Foundations and gaps in the literature	13
Four studies, one purpose	14
Data collection and methodology	14
Summary of the thesis chapters	15
1 More Bins, More Waste? Unpacking the Impact of Curbside Separation in Hungary	18
1.1 Introduction	18
1.1.1 Residential engagement in waste separation programs . .	20
1.1.2 Unexpected effects of the circular economy	22
1.2 Data and research design	24
1.2.1 Administrative data	24
1.2.2 Survey data	27
1.3 Methodology	29
1.4 Results	30
1.4.1 Regression results	30
1.4.2 Survey findings	34
1.5 Discussion	37
1.6 Conclusions	38
2 Recycling Gains and Material Losses: A Panel Analysis of Household Waste Trends in a Decade of Disruption	40

2.1	Introduction	40
2.1.1	Theoretical background	43
2.1.2	Changing consumption and waste generating patterns	44
2.1.3	New solid and household waste generation and recycling habits	46
2.2	Data and research design	49
2.3	Methodology	53
2.4	Results and discussion	57
2.4.1	Results of the panel regression	57
2.4.2	Excess-over-expected method	60
2.4.3	Differences in waste generation across municipalities	64
2.5	Conclusions	67
3	Behavioral Response to Convenience: A Natural Experiment on Door-to-Door Selective Waste Collection	69
3.1	Introduction	69
3.1.1	Theoretical background	71
3.1.2	Inconsistent mechanisms behind waste generation	72
3.1.3	Waste management systems and consumer behavior	74
3.2	Materials and methods	78
3.2.1	Data and research design	78
3.2.2	Methodology	81
3.3	Results and discussion	84
3.4	Discussion	88
3.5	Conclusions	90
4	Is It Greener on the Right Side? – The Relationship Between Political Preferences and Environmental Behavior from Hungary	92
4.1	Introduction	92
4.2	The connection between political attitudes and environmental behavior	94
4.3	Data and methodology	96
4.4	Results	102
4.5	Discussion	104
4.6	Conclusions	107

Policy Implications	109
Bibliography	113
Appendix	143
List of Publications Related to the Dissertation	165

List of Figures

1.1	Total monthly waste generation (kg per capita)	25
1.2	Perceived behavioral impact of waste separation on consumption habits	35
2.1	Amount of waste (kg) generated and collected separately in Hungary	51
3.1	Parallel trends assumption	84
4.1	Amount of waste generated and collected separately in Budapest	98
4.2	Share of respondents indicating climate change as a serious problem	99
4.3	Change in voting share of left-wing parties (panel A) and per capita waste collected separately (panel B) from 2014 to 2019 in the districts of Budapest	102

List of Tables

1.1	Descriptive statistics	26
1.2	Distribution of the post-weighted sample (identical to the Hungarian population aged 18 and over)	28
1.3	Difference-in-difference regression results (change from street containers to the bag system)	31
1.4	Difference-in-difference regression results (change from the bag system to the double-bin system)	32
1.5	Comparison of OLS and TWFE estimates for waste outcomes	33
1.6	Descriptive statistics of the relevant survey questions	36
2.1	Descriptive statistics of the dataset	49
2.2	Settlement type distribution	50
2.3	Description of the variables	52
2.4	Panel regression results with time trends	58
2.5	Panel regression results with time trends and additional controls	60
2.6	Panel regression results on excess waste estimated based on time trends (2020–2023)	61
2.7	Panel regression results on excess waste estimated based on time trends and additional controls (2020–2023)	63
2.8	Heterogeneity analysis across the municipalities (2012–2023)	66
3.1	Descriptive statistics of the variables	79
3.2	Descriptive statistics of municipalities	81
3.3	TWFE regression results for selective and mixed waste	85
3.4	Placebo TWFE regression results for selective and mixed waste	86
3.5	Leave-one-out robustness check (Interaction effects only)	87
4.1	Descriptive statistics of the variables (annual district-level data)	101

4.2	Regression results (dependent variable: vote share of left-wing parties)	103
A.1	Facebook Groups and Group Sizes	143
A.2	Survey questions in English	148
A.3	Settlements and Their Populations	151
A.4	List of Settlements	161
A.5	Coding scheme for the candidates/parties to be considered left- or right-wing.	162
A.6	Regression results (dependent variable: vote share of left-wing parties).	164

Acknowledgments

I dedicate this thesis to my wife, Anetta, who has supported me unwaveringly from the very beginning. I would also like to thank my family living in Ukraine: my mother, who regularly visited and brought the feeling of home with her; my father, whom I have not seen in person for years, yet has provided me with invaluable support from afar. I am also grateful to my supervisor, Bakó Barna for his patience and unparalleled expertise, which greatly supported my work. I would like to thank the opponents invited to the pre-defense, Mizik Tamás and Hajdu Tamás, for their professional comments and suggestions, as well as all my colleagues and friends at Corvinus University of Budapest. Last but not least, I would like to honour the memory of my grandmother, Ráti Margit, as she sadly did not have the chance to see it completed.

Introduction

Achieving sustainability is one of the most important global challenges that will shape the future of social, economic, and environmental development. Limited natural resources, a growing population, and consumption driven by economic growth present complex problems that require comprehensive strategies to address. Waste generation and management is a key element of sustainability, as it involves reducing waste, recycling effectively, and handling materials in an environmentally sound way.

The scientific study of this issue has received considerable attention in recent decades, particularly from the perspective of the circular economy and sustainable consumption. Several studies have addressed the issue of increasing the efficiency of waste management (Malinauskaite et al., 2017; Haupt et al., 2016), the functioning of selective waste collection systems (Iriarte et al., 2009; Ibrahim, 2020), and the technological potential of recycling (Tomić and Schneider, 2020; Victar and Waidyasekara, 2024). However, the literature still pays little attention to the mechanisms and behavioral factors that influence the evolution of waste generation and the efficiency of sustainable waste management systems.

The aim of my dissertation is to provide a deeper understanding of these relationships and to highlight the role of consumption patterns, the availability of selective household waste collection, and social and economic factors in shaping sustainability. Achieving the SDGs will require not only technological and infrastructural improvements but also a deeper understanding of and incentives for behavioral patterns related to waste generation.

Foundations and gaps in the literature

The existing literature on waste management – as will be discussed in later chapters – focuses mainly on the principles of the circular economy, the promotion of sustainable consumption, and the efficiency of waste management systems. Much of this research examines how socio-demographic factors influence littering patterns or how different policies (e.g., selective waste collection, recycling programs) contribute to sustainability goals. Various theoretical models (e.g., Theory of Planned Behavior, Attitude Model) are used to explain and predict people’s environmental behavior, and the study of sustainability attitudes and political preferences is becoming increasingly popular.

However, despite the diversity and breadth of the literature, there are still significant gaps in many areas. Research often assumes that selective waste collection reduces waste generation, but there is little empirical evidence to support this, especially with regard to the circular economy rebound effect (Figge and Thorpe, 2019; Bączyk et al., 2024), which is a very under-researched area. The environmental impact of the COVID-19 pandemic has also received little attention from researchers, while the pandemic may have had not only short-term but also long-term negative effects on consumption and waste generation patterns (Abirached Fernández et al., 2021). Research on the efficiency of waste management systems tends to treat changes in the social and economic environment in isolation, without considering their combined effects. The literature on the relationship between political preferences and environmental behavior is mainly based on self-report questionnaires. Therefore, empirical evidence on the impact of ideological attitudes on actual waste management behavior remains limited.

The primary aim of the chapters presented here is to fill gaps in the literature and provide new perspectives on the interrelationships between waste management systems, social attitudes, and sustainability processes. Each paper reflects on an under-researched area, adding empirical evidence to previous theoretical assumptions and new approaches to the scientific discourse.

Four studies, one purpose

Although the individual chapters may appear to deal with separate issues, the research as a whole forms a coherent framework. All four studies explore the complex relationship between waste management and sustainability, focusing on different aspects but with a common goal: to fill existing gaps in the literature and to better understand the mechanisms that shape sustainability processes.

The first study examines the impact of the introduction of selective waste collection on total waste generation and provides empirical evidence for the existence of the circular economy rebound effect. The second study investigates the pandemic's broader impact on consumption and municipal waste generation, while the third combines this perspective with changes in selective waste collection infrastructure, providing a unique natural experiment framework. The final study analyzes the relationship between political preferences and environmental behavior, challenging the often-voiced assumption that left-wing orientation automatically implies greater environmental awareness.

Even though these topics focus on different areas, the research as a whole provides a coherent picture of the complex relationship between waste management systems and sustainability. The chapters build on and complement each other, and together they highlight the fact that the study of waste management efficiency is not simply a technological or regulatory issue, but a set of social, economic, and behavioral factors that can only be properly understood through an integrated approach.

Data collection and methodology

The first study examines the impact of the introduction of separate collection systems on total waste generation. I used administrative data from a Hungarian non-profit waste management company (Depónia Kft.). The database included household waste quantities for one city and ten smaller municipalities between 2009 and 2018. For data analysis, I used the difference-in-differences (DID) method, which allows comparing the implementation of different collection schemes and quantifying their impact.

The second study examines the impact of the COVID-19 epidemic on waste generation patterns. For the data analysis, I used official waste management data and macroeconomic indicators available free of charge from the Central Statistical Office (KSH) to analyze the differences between pre- and post-epidemic consumption patterns. Time series regression models were used to examine changes in the data over time, with a particular focus on long-term changes in consumer behavior due to the crisis situation.

The third study focuses on the combined analysis of the effects of selective waste collection systems and COVID-19. For this paper, I combined household waste data available at the KSH with socio-demographic indicators that allowed me to examine the impact of the introduction of selective waste bins and the restrictions caused by the COVID-19 epidemic on sustainable waste management. The analysis used panel regression methods to model differences between regions and time periods.

The fourth study examines the relationship between policy preferences and environmental behavior. Previous research has often relied on self-report questionnaires, but this study used observational data: it examined how political ideology influences environmental behavior by linking election results to actual rates of separate waste collection. Statistical analyses were conducted using correlation and causal inference models, which allowed the relationship between political attitudes and actual behavior to be explored.

Summary of the thesis chapters

The results of the first chapter show that the introduction of door-to-door selective collection systems does not necessarily reduce overall waste generation and, in some cases, may even lead to an increase in consumption. In fact, the easier availability of selective collection may change household consumption patterns, as the possibility of recycling may provide a kind of "exemption" from environmental responsibility and contribute to higher waste generation. This suggests that selective collection does not replace attitudes towards waste reduction but rather acts as a parallel process. This may be due to the circular economy rebound effect, which was supported by survey results. The study was the first in the literature to directly link this phenomenon to the use of curbside collection.

The second chapter presents an analysis of municipal waste trends over a decade, with special emphasis on the disruptions caused by COVID-19, including panel regressions and an “excess-over-expected” framework. Findings show an increase in selective (recyclable) waste collection alongside a rise in total waste generation, indicating a rebound effect in consumption. Urban areas experienced the largest growth in selective waste, likely due to better infrastructure and heightened e-commerce activity. The study innovatively applies the COVID-19 Stringency Index to quantify policy intensity, revealing a strong correlation between regulatory measures and waste fluctuations. Despite increased recycling, contamination and inefficient practices have offset environmental gains, challenging the assumption that recycling alone leads to sustainability. The research offers a multidimensional view of pandemic-era waste behavior and emphasizes the need for integrated policies, robust infrastructure, and public engagement to support a circular economy and resilient post-pandemic waste systems.

In the third chapter, the behavioral effects and impact of door-to-door selective waste collection systems were evaluated through a natural experimental design, using the COVID-19 pandemic as an exogenous shock. A two-way fixed effects (TWFE) regression model, based on a difference-in-differences (DiD) approach, was applied to municipal-level panel data collected from 93 Hungarian municipalities between 2012 and 2023. The aim of the research was to isolate the causal impact of selective waste collection infrastructure under conditions of external pressure. Municipalities equipped with curbside bin systems were found to generate, on average, 11.76 kilograms more selectively collected waste per capita annually compared to municipalities without such systems, while the volume of mixed waste remained stable. These findings suggest that the presence of convenient waste sorting infrastructure contributed to an increase in overall waste generation, rather than a substitution between waste streams. This outcome has been interpreted as evidence of what I refer to as the Perceived Disposal Ease Bias, whereby the effortlessness of disposal encourages higher material throughput. The results underscore the importance of accounting for behavioral responses when evaluating the environmental effectiveness of waste management policies. It is recommended that convenience-enhancing infrastructure be supplemented with targeted communication and behavioral interventions to ensure alignment with sustainability objectives. To the best of my knowledge, this study represents one of the first empirical applications of a

quasi-experimental framework to assess the behavioral implications of selective collection systems under external shocks.

The fourth chapter examines the links between political attitudes and environmental behavior, specifically the actual practice of waste selection and its relationship to electoral outcomes. Public perception and some of the literature suggest that individuals with left-wing political views are more likely to support environmental causes and lead more sustainable lifestyles. However, the study, which correlated electoral outcomes in Budapest with separate waste collection rates in different districts, found that the opposite was true in Hungary when looking at actual behavioral data. The empirical analysis showed that districts dominated by left-wing voters had lower rates of separate waste collection, while districts supported by right-wing voters had higher rates of separate waste collection. Another important factor is income and access to infrastructure. The data show that higher-income areas had higher rates of selective waste collection, while recycling rates remained lower in lower-income areas, regardless of political preferences. This is consistent with the "too poor to be green" theory, which suggests that lower-income households have fewer resources to engage in environmental practices, even if they are otherwise committed to sustainability goals.

Chapter 1

More Bins, More Waste? Unpacking the Impact of Curbside Separation in Hungary

1.1 Introduction¹

Managing the ever-increasing volume of waste is one of the biggest challenges of the 21st century. Curbside selective waste collection, which in theory has a positive impact on consumption patterns, may contribute to addressing this challenge, as numerous studies have shown that door-to-door collection encourages participation in the circular economy (Xu et al., 2017; Folz, 1991; Struk, 2017; Abbott et al., 2011). Abbott et al. (2011) specifically noted that curbside collection is a key factor in improved recycling performance in the UK, while Folz (1991) demonstrated that curbside collection can engage nearly twice as many people compared to other methods. However, while source separation impacts waste disposal rates, it can also influence overall waste generation, and the effect can be either positive or negative, depending largely on residents' attitudes and behaviors.

The introduction of waste separation programs, such as curbside recycling, is often accompanied by information campaigns and awareness-raising efforts (Bernstad et al., 2013). These initiatives aim to improve public understanding of the environmental and social impacts of waste generation and highlight

¹This study is the result of many years of dedicated research with the assistance and guidance of Bakó Barna and Berezvai Zombor. A previous version of this chapter was published in a working paper. That earlier version was based on my Master's thesis and has been substantially revised and expanded for inclusion in this dissertation.

that not all waste can be recycled. As a result, some individuals may reduce the overall amount of waste to adopt more environmentally friendly practices. However, a paradoxical shift in consumer behavior may also occur when curbside waste collection is introduced, especially if it goes hand in hand with the introduction of separate waste bins. In some cases, the availability of recycling bins may inadvertently increase waste generation or household consumption (Maier et al., 2023). The observed increase in waste generation may be attributed to the circular economy rebound effect (Siderius and Poldner, 2021; Castro et al., 2022) – this may lead people to feel that waste collected separately does not count as rubbish, so they become less mindful of their consumption and end up producing more waste.

The existence of the circular economy rebound effect is not new, but so far researchers have not investigated the phenomenon through different selective collection methods. Moreover, the behavioral response to various waste collection strategies is currently unclear, while understanding these reactions is essential for the design of effective recycling programs. This study examines the effect of different waste separation methods on overall waste generation in Hungary. To gain further insight into the potential behavioral shifts caused by the circular economy rebound effect, a survey was conducted. This unique approach to the issue aimed to reveal whether the implementation of specific waste separation methods – such as bag-based versus bin-based collection – affected not only the volume and composition of waste, but also residents' littering behaviors.

In this paper, I examine the impact of various curbside collection methods on waste generation. The results indicate that introducing more convenient source-separated waste collection methods increases the volume of source-separated waste but does not reduce the amount of non-separated waste. This implies that source separation may unintentionally lead to a net increase in total waste generation, likely due to a circular economy rebound effect. Survey findings further support this conclusion. These results raise concerns about the continued expansion of the double-bin waste separation system and emphasize the urgent need to better understand the factors and mechanisms that influence waste generation behaviors.

The study makes significant contributions to the existing literature in at least two ways. First, it estimates the impact of waste separation methods on municipal waste generation – an area that remains under-researched in the

academic literature. Second, it also aims to explore the behavioral factors behind the impacts identified, offering a deeper understanding of the mechanisms behind waste generation. The results have important policy consequences.

1.1.1 Residential engagement in waste separation programs

Developing good waste management practices is critical to achieving sustainability goals. In particular, understanding the human dimensions of waste management is important, as source separation results in cleaner and higher quality recyclables than mixed waste, increases recycling rates, and reduces pressure on landfills (Bennagen et al., 2002). However, the effectiveness of curbside collection systems is far from trivial and is influenced by a number of factors, not always in a positive way.

The Theory of Planned Behavior (TPB) was developed to predict human behavior. The concept was developed by Icek Ajzen and has since been widely applied to the study of sustainability behavior, including waste management behavior (Ajzen, 1991).

According to the TPB, the performance of a given action depends on the individual's intention, which is shaped by three key factors: attitudes, subjective norms and perceived behavioral control. For example, the theory suggests that the success of door-to-door selective waste collection depends largely on people's attitudes, or the extent to which they perceive the system to be useful and beneficial. If they perceive that separate collection contributes to environmental protection and reduces the burden on landfills, they are more likely to participate. On the other hand, if the system is perceived as complicated or inconvenient, it can create negative attitudes that may discourage participation.

Subjective norms also play an important role. If separate waste collection is generally accepted and supported in a residential community or family environment, individuals are more likely to participate. Perceived behavioral control, i.e., the individual's sense of being able to perform the desired behavior, is also a key factor. If the door-to-door system works well, the infrastructure is adequate, and the collection process is easy to follow, people are more likely to participate. Conversely, if they feel that there is insufficient information

about separate collection or that waste management systems are not working effectively, then perceived control and therefore willingness to participate may be reduced.

All of this suggests that individuals with pro-environmental attitudes are more likely to participate in selective waste collection (Tonglet et al., 2004). Further developing the theory, Groot and Steg (2007) emphasize that integrating environmental concerns into the TPB improves its predictive ability because these concerns influence attitudes, norms, and perceived control. Han (2015) further strengthens this approach by showing that personal norms and values significantly influence pro-environmental behavior. Hassan et al. (2015) take a different approach and highlight the importance of cultural factors, while Hidalgo-Crespo and Amaya-Rivas (2024) extend the TPB to include factors such as environmental awareness and community involvement.

The Theory of Planned Behavior therefore provides an effective framework for studying the implementation of door-to-door collection systems, as it allows the identification of the main factors influencing public participation. However, it should be noted that intentions do not always translate into actual actions (Wang and Mangmeechai, 2021; Yuriev et al., 2018). In fact, the TPB often ignores habitual or routine behaviors, such as selective waste collection, and focuses primarily on intentional decisions. It also oversimplifies social impacts, reducing them to subjective norms and ignoring the complexity of social dynamics. It also underestimates the role of emotions and moral values, and does not adequately address external barriers such as lack of infrastructure or economic constraints.

Although the TPB is well suited to studying the effects of curbside collection programs, it cannot always explain differences in attitudes and intentions, i.e., why someone does not implement environmentally friendly behavior despite intending to do so. This represents a significant limitation. According to one Eurobarometer survey, 66% of Hungarian respondents sort waste correctly and 66% of them consider it important to promote a circular economy, such as waste reduction and recycling (European Commission, 2024). However, the recycling rate in 2024 is just over 30% in Hungary, while the EU27 average is close to 50%, and only Portugal, Greece, Cyprus, Malta, and Romania performing worse (European Environment Agency, 2024), despite the fact that some form of selective waste collection (selective island or curbside collection)

has been available throughout the country since January 1, 2015 (Hungarian Government, 2012).

Many studies have therefore taken a very different, more practical approach. Ibáñez et al. (2011) used statistical models to study municipal waste separation programs. Their results show that income and education levels play a crucial role in the willingness to participate, while infrastructure development significantly improves the success of programs. Mbiba (2014) used a qualitative approach of interviews and field observations to understand the relationship between waste characteristics and household willingness to separate in Eastern and Southern Africa.

Best and Kneip (2011) experimentally investigated the impact of convenience, concluding that reduced time and resource requirements increase participation. The questionnaire survey by Owusu et al. (2013) in Ghana focused on the impact of economic incentives and used quantitative analysis to analyze household behavior. The study showed that incentives alone are not sufficient to achieve high participation rates in the absence of adequate infrastructure and information. The latter was also confirmed by a field study in Sweden (Bernstad et al., 2013), which found that interpersonal communication significantly increased participation, especially in the case of food waste separation. Other studies (Manomaivibool et al., 2018) have examined the role of social factors and educational campaigns (Xiao et al., 2017), while Oyekale (2017) has explored the role of access to information and regulations. The issue is therefore extremely complex, and it is far from clear whether participation in various sustainability programs automatically makes initiatives effective or has a positive impact on sustainability.

1.1.2 Unexpected effects of the circular economy

While several studies aimed to identify the drivers of waste generation (Salkie et al., 2001; Johnstone and Labonne, 2004; van Beukering et al., 2009; Parizeau et al., 2015; Lebersorger and Beigl, 2011; Talalaj and Walery, 2015; Ghinea et al., 2016) and the factors affecting residential involvement and success of a waste separation program, only a couple of studies (Aphale et al., 2015; Grazhdani, 2016; Maier et al., 2023) analyzed the effect of the interac-

tion of the two and highlighted that well-intentioned recycling initiatives may sometimes result in unintended behavioral responses.

Grazhdani's findings in Prespa Park, Albania show that while augmented recycling infrastructure led to a rise in separated waste, it also drove a 10% rise in total per capita waste, suggesting that the presence of additional capacity led residents to produce more waste. Similarly, Maier et al. (2023) observed a 6–10% increase in waste generation in areas in North Carolina where curbside collection of recyclable waste was introduced.

One potential explanation could be the circular economy rebound effect. This is a relatively new, but rapidly emerging concept in the analysis of sustainability strategies. The phenomenon suggests that the positive effects of various sustainability policies may be partially or fully offset by unintended negative consequences of these interventions (Figge and Thorpe, 2019). Vivanco et al. (2016) describe this as a behavioral response whereby perceived environmental benefits justify increased resource use. Castro et al. (2022) further argue that the rebound effect often undermines the objectives of a circular economy, as individuals change their consumption patterns under the influence of enhanced waste management schemes, leading to an overall increase in waste generation. Milios (2017) also conceptualizes this as a paradox of knowledge, where increased knowledge of recycling opportunities creates a false sense of sustainability, encouraging individuals to consume more and believe that recycling will mitigate their impact.

Ibrahim (2020) and Li and Xu (2022) approached the problem from a different perspective. In their study they conclude that despite improvements in waste management, increasing demand for recyclable materials may create new sources of waste, especially if economic growth outpaces waste management capacity. Siderius and Poldner (2021) found that the cost effectiveness of recycling encourages the consumption of new products rather than the use of recycled products. Moreover, from an energy perspective, Domenico et al. (2022) used macroeconomic models to show that increasing energy efficiency does not always reduce environmental impacts, as the resources saved are often used for new consumption patterns.

Overall, the rebound effect of the circular economy is a significant barrier to achieving sustainability goals. This highlights the limitations of circular economy models when implemented in isolation. Comprehensive strategies are needed to address such impacts (Zerbino, 2022; Zerbino and Aloini, 2022),

and focusing on short-term outcomes, such as rapidly increasing selective waste volumes or recycling rates, may do more harm than good in the long run (Chen, 2021; Wiesmeth, 2021).

However, to the best of my knowledge, the phenomenon has not yet been directly linked to the use of curbside waste collection, leaving gaps in understanding the mechanisms behind observed changes in consumption behaviors and waste generation.

1.2 Data and research design

1.2.1 Administrative data

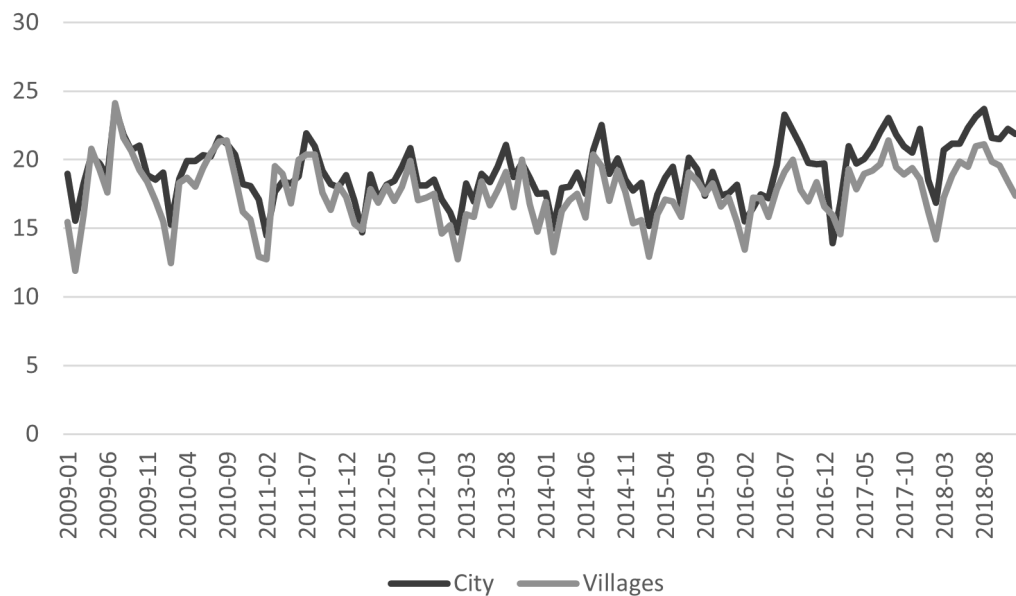
The data used for this research was collected from a local non-profit waste management company Depónia Kft. The dataset contains monthly quantities of source-separated and non-separated waste from one city (Székesfehérvár) and ten smaller towns and villages separately from 2009 to 2018. The dataset only includes the amount of waste collected from households; no other collection method is included. The reason for this is that the method of curbside collection differs between cities and villages.

Curbside collection of source-separated waste was implemented in Székesfehérvár in 2009. The initial system required that paper, plastic, and aluminum be collected separately and placed in separate transparent bags. These bags were required to be placed on the pavement for collection on specific days. This is referred to as the “bag system.” In mid-2016, the bag system was replaced with the so-called “double-bin system.” This means that households were provided with an additional bin for source-separated waste, i.e., for paper, plastic, metal, and aluminum. Non-recyclable and biodegradable waste should be placed in the other bin, as was the case previously.

Villages followed a different path. Source-separated waste collection was managed through large containers placed in public spaces, mainly along streets and in public squares. This system was changed to curbside collection (“bag system”) in early 2013, with residents required to collect recyclable waste in transparent bags and place them in front of their house on predefined days.

The implementation of the different collection methods enables the estimation of the impact of these collection methods on the quantity of waste generated and on the recycling rate. The dataset contains 120 observations for both the smaller settlements and the city. To obtain per capita waste generation data, the total amount of waste collected was divided by the population. Figure 1.1 illustrates the two series of data. The per capita waste generation data demonstrates comparable trends and seasonal patterns in both the city and the villages included in the study. There is a slight decline in the first part of the period, followed by an uptick after approximately 2015. This may be attributed to the enhanced economic performance and consequently higher income levels in Hungary.

Figure 1.1: Total monthly waste generation (kg per capita)



Note: The data cover the volume of both source-separated and mixed waste.

One of the most substantial factors influencing waste generation is the level of income (e.g., Johnstone and Labonne, 2004, Talalaj and Walery, 2015). In order to control for the income of residents, personal taxable income data was obtained from the Hungarian Central Statistical Office (KSH). The dataset comprises annual data at the settlement level. To ensure consistency with the waste data, a weighted average of per capita income was calculated for

those settlements where waste generation data were available. Furthermore, a dataset on monthly gross wages and salaries was employed to disaggregate the annual taxable income data into monthly data. As the gross wages and salaries dataset is only available at the county level, within-year differences were adjusted for county-level variation for both villages and the city.

Table 1.1: Descriptive statistics

Variable	Obs.	Mean	Median	St. dev.	Min	Max
Village dataset (per capita)						
Taxable income (thousand HUF/month)	120	89.4	84.1	22.2	59.0	147.9
Source-separated waste generation (kg/month)	120	0.3	0.2	0.3	0.1	1.0
Not source-separated waste generation (kg/month)	120	17.3	17.3	2.1	11.7	23.9
Total waste generation (kg/month)	120	17.6	17.6	2.2	11.9	24.1
Recycling rate (%)	120	1.7	1.0	1.3	0.3	4.8
City dataset (per capita)						
Taxable income (thousand HUF/month)	120	105.2	99.6	22.9	72.0	166.7
Source-separated waste generation (kg/month)	120	1.1	0.9	0.5	0.5	2.6
Not source-separated waste generation (kg/month)	120	18.0	18.0	1.9	12.5	22.9
Total waste generation (kg/month)	120	19.1	18.9	2.1	13.9	23.9
Recycling rate (%)	120	5.8	4.9	2.2	3.0	11.8

The descriptive statistics of the variables are presented in Table 1.1. A comparison between the village and city datasets reveals that income is higher in cities, as is waste generation. Both differences are statistically significant at

all conventional significance levels ($p < 0.001$), supporting the argument that income may be a driver of waste generation.

Another somewhat surprising result is that the recycling rate is significantly higher ($p < 0.001$) in the city than in the villages. This may be attributable to the different collection methods described above. The preliminary findings indicate that the double-bin system is more effective in source separation than the bag system. It is important to note, however, that this comparison may not fully account for the differences in collection methods. The mean recycling rate represents the entirety of the study period. However, in Székesfehérvár, curbside collection was available for nearly the entire duration of the study. In contrast, the curbside collection system was only implemented in the villages in 2013.

1.2.2 Survey data

An anonymous online survey was conducted to gain a deeper understanding of the mechanisms that influence littering habits. The questionnaire was shared in carefully selected public Facebook groups, mainly specific to the place of residence and region, to ensure a diverse sample and to be as representative as possible of Hungarian society in terms of gender, age group, and region.

This method is particularly suitable for studying social phenomena that require broad participation. Best practices in social media research (Kosinski et al., 2015; Wilson et al., 2012; Fricker, 2008) were consistently applied during data collection. The questionnaire was designed using the Google Forms platform, which ensured respondent anonymity. Completion was voluntary, and participants were provided with detailed information about the data handling policy and the research aims at the beginning of the questionnaire.

The data collection took place between 28 October and 5 December – by then, the bin-based system was already widespread, so the questionnaire could not compare different collection methods. The survey was shared in 122 Facebook groups, each with at least 1,000 members; the full list is provided in the appendix. A total of 4041 responses were collected. Responses with missing information and invalid entries were deleted, which led to a final sample size of 3950. The sample was post-weighted to ensure representativity for gender, age group, highest level of education and region (as shown in Table 1.2). The

textttanesrake function of R was applied for post-weighting that applies the raking post-stratification method described by DeBell and Krosnick (2009).

Table 1.2: Distribution of the post-weighted sample (identical to the Hungarian population aged 18 and over)

Variable	Distribution
Sex	
Male	48%
Female	52%
Age	
18–29	16%
30–39	16%
40–59	36%
60+	32%
Region	
Central Hungary	32%
Central Transdanubia	11%
Western Transdanubia	10%
Southern Transdanubia	9%
Northern Hungary	11%
Northern Great Plain	15%
Southern Great Plain	12%
Highest level of education	
Primary	17%
Secondary	57%
Tertiary	26%

Note: Own data collection post-weighted using the data published by the Hungarian Central Statistical Office.

The questionnaire consisted of 24 questions. The full survey (originally administered in Hungarian) is provided in English in the appendix (Table A.2). Four questions were demographic in nature (gender, age group, highest level of education, region), while the rest included both direct and hypothetical questions connected to waste generation. The objective of these questions was to discover participants' recycling habits, perceptions of packaging waste, and the impact of recycling convenience on their consumption habits. The questions

were measured on a 1-5 Likert scale, with 1 indicating that the respondent strongly disagrees with the statement and 5 indicating that the respondent strongly agrees. This approach yielded qualitative insights into the influence of latent behavioral factors – such as the circular economy rebound effect – on waste generation under different curbside collection methods, thereby complementing the quantitative data.

1.3 Methodology

The dataset covers three different collection methods that were implemented at disparate times and locations, thereby enabling the application of regression methodology in a difference-in-differences (DiD) framework. The analysis is conducted separately for each intervention using a standard 2×2 specification, with separate regressions estimated for the bag and the double-bin interventions. Treatment effects are estimated using ordinary least squares (OLS) regression including dummy variables as controls. This approach allows for the separate interpretation of all explanatory variables and supports greater flexibility in model specification. Explicit dummies and interaction terms make the identification strategy transparent and facilitate comparison across groups.

As the dataset consists of time series data exhibiting considerable within-year seasonality (Figure 1.1), month and year dummy variables were included in the model. The OLS specification also incorporates time-invariant group indicators (e.g., types of settlements where specific waste collection systems were implemented) and interaction terms capturing the treatment effects of interest. Additionally, the model includes the average taxable income per capita as a time-varying covariate to control for local economic conditions. To account for potential heteroscedasticity and autocorrelation in the error term, robust standard errors were used. The estimated model is as follows:

$$y_{it} = \beta_0 + \beta_1 \text{Location}_i + \beta_2 \text{Time}_t + \beta_3 (\text{Location}_i \times \text{Time}_t) + \beta_4 \text{Income}_{it} + \text{Month}_t + \text{Year}_t + u_{it}, \quad (1.1)$$

where y_{it} denotes the outcome variable (e.g., waste quantity or recycling rate) for settlement i in month t . Location_i is a binary indicator equal to

1 for settlements targeted by a specific intervention (e.g., rural areas for the bag system, or the urban area for the double-bin system). $Time_t$ is a dummy variable that refers specifically to the post-treatment period within the treated group and thus identifies the intervention effect. The variable of interest, β_3 , captures the causal effect of the introduction of the new collection system. This is the DID estimate. $Month_t$ and $Year_t$ are dummy variables accounting for seasonal and annual effects, while u_{it} is the idiosyncratic error term.

While alternative estimation strategies such as two-way fixed effects (TWFE) models are common in difference-in-differences (DiD) settings, the choice of OLS is justified by several characteristics of the data and research design. Most importantly, the dataset comprises a limited number of observational units, which could make fixed effects estimation sensitive to overfitting and downward-biased standard errors. In such low-cluster settings, inference in TWFE models might become unstable. Nevertheless, TWFE models are also estimated and presented in this study as a robustness check, confirming the consistency of the main results.

1.4 Results

An integrated approach was used to understand the impact of introducing separate waste collection. First, quantitative data and difference-in-difference methods were used to examine the impact of different waste collection methods on waste generation. This was followed by a questionnaire analysis to identify residents' attitudes, behaviors and perceptions regarding waste separation and waste generation, which may reveal latent factors such as social pressure, convenience or the circular economy rebound effect. This approach provides a comprehensive understanding of the factors influencing waste generation and the potential unintended consequences of different waste separation methods.

1.4.1 Regression results

First, the focus was on the transition from street containers to the bag system. Prior to 2013, street containers were used in the villages to collect source-separated waste. In that year, curbside collection was rolled out in

the villages using the bag system. No further modifications were made. This model covers the period from January 2010 to December 2015. During this period, the collection method employed in the city was not modified, thereby providing an optimal benchmark for comparison.

In contrast, the bag system-based curbside collection was initiated in Székesfehérvár in 2008. In 2009, the program was extended to encompass the entire city. In mid-2016, the bag system was replaced by the double-bin system throughout the city. No additional changes were introduced. In the second model, the time period under investigation spanned from January 2014 to December 2018. During this period, the collection method in the villages remained unchanged, thereby providing an ideal benchmark for comparison.

Table 1.3: Difference-in-difference regression results (change from street containers to the bag system)

Variables	(1) Total amount of waste	(2) Non-separated amount of waste	(3) Source-separated amount of waste	(4) Recycling rate
Effect of the introduction of the bag system	-0.342 (0.330)	-0.366 (0.333)	0.024 (0.029)	0.103 (0.151)
Villages	-0.853 (0.684)	-0.234 (0.686)	-0.618*** (0.065)	-3.258*** (0.337)
Time of the bag system	-1.508 (1.054)	-1.510 (1.063)	0.002 (0.099)	0.254 (0.546)
Taxable income	0.016 (0.039)	0.010 (0.039)	0.006 (0.004)	0.032 (0.021)
Constant	16.542*** (3.065)	16.200*** (3.062)	0.342 (0.317)	1.795 (1.715)
Month dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
N	144	144	144	144
R ²	0.785	0.754	0.953	0.955

Table 1.3 shows the regression results, which indicate that the implementation of the curbside system using bags had no significant impact on the volume

of total waste, non-separated waste and source-separated waste. Consequently, it also had no effect on the recycling rate. Furthermore, the findings suggest that the quantity of source-separated waste and, consequently, the recycling rate are typically lower in villages than in the city. Taxable income had no effect on the amount of waste generated in this period.

The second analysis examined the impact of a change in the collection method in Székesfehérvár. The results are presented in Table 1.4.

Table 1.4: Difference-in-difference regression results (change from the bag system to the double-bin system)

Variables	Total Waste	Mixed Waste	Selective Waste	Recycling Rate
Effect of the introduction of the double-bin system	0.815** (0.334)	0.314 (0.322)	0.501*** (0.054)	1.701*** (0.247)
City	-1.861** (0.891)	-2.492*** (0.865)	0.631*** (0.131)	4.883*** (0.601)
Time of the double-bin system	0.584 (0.407)	0.742* (0.397)	-0.158** (0.071)	-0.649* (0.360)
Taxable income	0.200*** (0.055)	0.196*** (0.052)	0.004 (0.008)	-0.071** (0.034)
Constant	-0.508 (4.667)	-0.171 (4.472)	-0.337 (0.613)	6.292** (2.808)
Month dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
N	120	120	120	120
R ²	0.877	0.835	0.954	0.954

The introduction of the double-bin system resulted in an average increase in source-separated waste volume of 0.5 kg/month/capita. However, this did not lead to a reduction in the amount of non-separated waste, resulting in a significant overall increase in waste generation. The increase in the volume of source-separated waste was considerable, with the amount prior to the introduction of the double-bin system being approximately 0.85 kg/month/capita. This represents an increase of almost 60%. The total quantity of waste generated exhibited an increase of approximately 4%. Furthermore, the recycling rate increased by an average of 1.7 percentage points, which is a notable in-

crease compared to the recycling rate prior to the introduction of the double-bin system (4.6%).

While the findings suggest a substantial impact of the double-bin system on waste generation and recycling behavior, it is essential to examine the robustness of these results. Given the limited number of observational units and the potential sensitivity of OLS, two-way fixed effects (TWFE) models are also estimated, controlling settlement and month fixed effects to account for unobserved heterogeneity. To ensure valid inference under intra-cluster correlation, standard errors are clustered at the settlement level.

The results, which compare OLS and TWFE estimates across outcomes, are summarized in Table 1.5.

Table 1.5: Comparison of OLS and TWFE estimates for waste outcomes

Variables	Double-bin system		Bag system	
	OLS	TWFE	OLS	TWFE
Total waste	0.815** (0.334)	1.197** (0.184)	-0.342 (0.330)	-0.195 (0.114)
Non-separated waste	0.314 (0.322)	0.589** (0.073)	-0.366 (0.333)	-0.212 (0.110)
Source-separated waste	0.501*** (0.054)	0.609** (0.132)	0.024 (0.029)	0.018 (0.014)
Recycling rate	1.701*** (0.247)	0.024* (0.007)	0.103 (0.151)	0.0003 (0.0002)

The comparison between OLS and TWFE estimates reveals a high degree of consistency across model specifications. In the case of the bag system, neither specification produces statistically significant results across any of the outcome variables. For the introduction of the double-bin system, both approaches indicate a substantial and statistically significant increase in total waste, source-separated waste, and the recycling rate. The TWFE model also shows a significant increase in non-separated waste, suggesting that although selective collection improved, it was accompanied by a parallel rise in overall waste generation, including non-recycled fractions. While the magnitude of the effect on total waste is larger under TWFE (1.197) than under OLS

(0.815), the estimated increase in the recycling rate is more pronounced in the OLS model (1.701) compared to TWFE (0.024), though both are statistically significant.

These results reinforce the robustness of the earlier OLS-based findings. The consistency in the direction and relative magnitude of the estimated effects across OLS and TWFE models provides additional confidence in the conclusion that the double-bin system had a more pronounced and reliable effect on household waste behavior than the bag system. In conclusion, the more convenient method of source-separated waste collection has been shown to result in increased waste generation, a finding that aligns with previous research (Grazhdani, 2016; Maier et al., 2023).

1.4.2 Survey findings

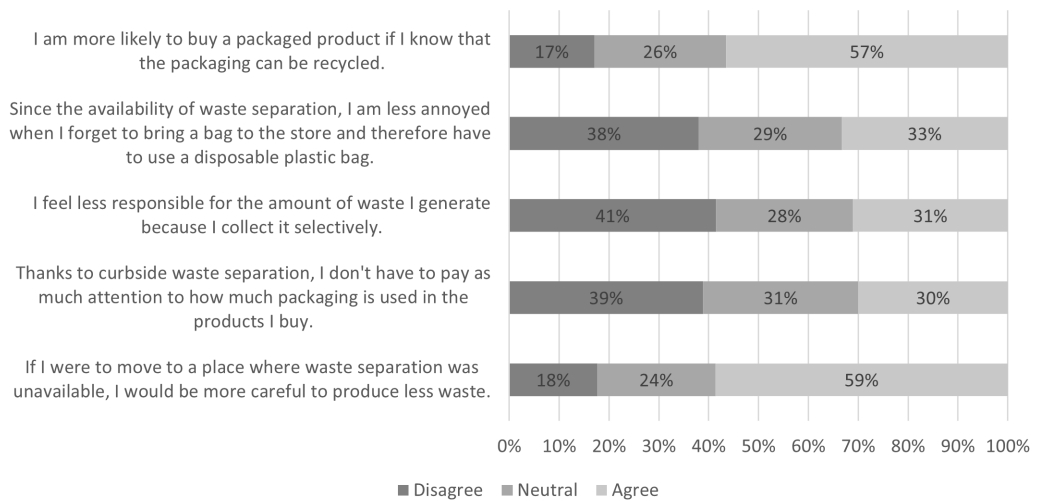
The regression results suggest that waste generation in the city increased by about 4% on average after the introduction of the more convenient source-separated waste collection. The potential reasons for this are shown in Table 1.6, which includes the relevant questions from the questionnaire along with descriptive statistics for each item.

Based on the responses, a large fraction of the respondents believe that waste separation can mitigate climate change and waste management problems. This shows that respondents largely agree with the environmental benefits of waste separation. Furthermore, residents are more likely to collect waste separately if the curbside collection method (double-bin system) is applied. However, it is also evident from the results that several residents pay less attention to the amount of waste they generate if curbside waste separation is available as recyclable waste is not perceived as real waste by many people.

As shown in Figure 1.2 18% of the respondents disagreed with the hypothetical statement that if they had moved to a place where there was no separate waste collection, they would produce less waste. 59% strongly or mostly agreed with this statement, which clearly shows that people have become more careless about their own consumption and waste generation due to the availability of waste separation. Statements such as “I feel less responsible for the amount of waste I generate because I collect it selectively.” and “Since the availability of waste separation, I am less annoyed when I forget to bring

a bag to the store and therefore have to use a disposable plastic bag.” also elicited a significant share of agreement, which is cause for concern, as 31% and 33% of the respondents said that they strongly or mostly agree with these statements, respectively.

Figure 1.2: Perceived behavioral impact of waste separation on consumption habits



Note: “Agree” corresponds to a rating of 4–5 on the 1-5 Likert scale, “Neutral” corresponds to a rating of 3, and “Disagree” corresponds to a rating of 1–2.

The very high percentage of positive responses to the statement “I am more likely to buy a packaged product if I know that the packaging can be recycled.” also suggests that respondents justify the purchase of packaged goods on the grounds of recyclability. This mindset underpins the circular economy rebound effect, where recycling gives ‘permission’ to consume more products that require disposal, assuming that recycling minimizes or completely eliminates the negative environmental impacts of waste generation.

Table 1.6: Descriptive statistics of the relevant survey questions

Variable (Likert-scale question)	Obs.	Mean	Std. dev.	Median
Waste separation contributes to the fight against climate change.	3,950	4.1	1.1	4
Waste separation can solve waste management problems.	3,950	3.7	1.1	4
I would like more information on how to separate waste properly.	3,950	3.4	1.3	3
Curbside waste separation is easy and convenient.	3,950	4.4	1.0	5
I think that curbside waste separation is a good solution.	3,950	4.4	1.0	5
The extra bins available at home make it easier to collect waste separately.	3,950	4.3	1.0	5
Curbside waste separation is more convenient than waste separation using large containers on the street.	3,950	4.2	1.1	5
Curbside waste separation allows me to collect waste separately more efficiently.	3,950	4.2	1.1	5
Since introducing curbside waste separation, I have been more careful in separating my waste properly.	3,950	3.9	1.3	4
I am more likely to buy a packaged product if I know that the packaging can be recycled.	3,950	3.7	1.3	4
If I were to move to a place where waste separation was unavailable, I would be more careful to produce less waste.	3,950	3.7	1.3	4
Since the availability of waste separation, I am less annoyed when I forget to bring a bag to the store and therefore have to use a disposable plastic bag.	3,950	2.9	1.4	3
Thanks to curbside waste separation, I don't have to pay as much attention to how much packaging is used in the products I buy.	3,950	2.8	1.3	3
I feel less responsible for the amount of waste I generate because I collect it selectively.	3,950	2.8	1.4	3
Thanks to waste separation, it doesn't matter how much waste I produce, because it will be recycled anyway.	3,950	2.3	1.4	2

1.5 Discussion

The research findings show that the implementation of more convenient curbside waste collection methods in Hungary increased the amount of waste collected separately, but this was not followed by a reduction in non-separated waste. Hence, the overall volume of waste generation increased significantly. This is a key finding showing that the collection method significantly impacts waste generation. The survey findings indicate that citizens indeed take less care of the amount of waste they generate, as it will be recycled anyway, and several residents believe that recyclable waste leaves no or only minimal negative environmental impact.

In this research, three collection methods were considered: street containers, curbside collection with the “bag system”, and curbside collection with the “double-bin system”. The bag system, which uses transparent bags, did not result in significant changes in waste generation. This suggests that the bag-based system was not necessarily more convenient than the previous container-based method – bags are collected on specific days, require proper storage until collection, and – since they are transparent – can be rejected by the waste management company if incorrectly sorted.

In contrast, switching to a double-bin system resulted in a significant increase in both separate and total amounts of waste. The bins have larger storage capacity and allow residents to get rid of waste more frequently. Furthermore, bins are not transparent, making it easier to dispose of communal or non-recyclable waste that may explain the high contamination rates observed.

The double-bin system increased the recycling rate by 1.7 percentage points, equating to 0.5 kg of additional source-separated waste per capita each month. However, this increase in recycling was counterbalanced by a significant increase in the contamination rates, with the double-bin system showing a contamination rate of 50-60% compared to the less than 20% in the bag system based on the data provided by the waste management company.

This finding is consistent with the circular economy rebound effect, which states that residents who believe they are making a positive contribution to the environment will feel less guilty and consume less sustainably. For example, plastic and paper bags were widely available in grocery stores during the study period. Due to the circular economy rebound effect, residents might have been

encouraged to use more bags and buy pre-packed products instead of bulk purchases, resulting in increased packaging waste. This behavioral change could be attributed to the rebound effect, in which the convenience of using separate collection methods shifted consumption patterns and increased overall waste generation.

The survey conducted during the study lends support to this idea. The responses are in line with what could have been expected based on the theory of the circular economy rebound effect. Convenience, perceived environmental benefits, and waste separation practices can stimulate the consumption growth of packaged goods. Respondents acknowledge the environmental benefits of waste separation, and they overall believe that it is a sufficient solution to the problem of increasing waste and reduces the motivation for waste reduction. This may inadvertently lead to higher levels of waste generation, especially as respondents feel less responsible for the amount of waste they produce.

However, this behavioral change is actually detrimental to the environment, as the waste hierarchy pyramid suggests that reducing waste is far more important from a sustainability perspective than recycling. In addition, waste separation has its own environmental costs, as waste has to be collected and treated separately, leading to increased transportation and CO₂ emissions. The results are in line with some previous studies (Grazhdani, 2016; Maier et al., 2023) and suggest that there is a need to rethink the existing waste separation and collection methods, as the environmental benefits may be small while the associated costs may be high (maintenance of infrastructure, free collection of source-separated waste). There may be better initiatives that can deliver more environmental benefits for the same investment or cost.

1.6 Conclusions

This research investigated how different waste separation methods impact the amount of waste generated and found empirical evidence for the circular economy rebound effect. Furthermore, utilizing the findings of a consumer survey the study also offers insight into the behavioral mechanisms that may drive this phenomenon. The results call attention to the fact that making waste separation easier and more accessible may unintentionally encourage

higher levels of waste generation as citizens largely believe that waste collected separately is recycled anyway, and, hence, does not harm the environment.

Furthermore, despite the higher collection rates, the more convenient waste separation method (the double-bin system) is less environmentally friendly than the less convenient one (the bag system) due to increased contamination and waste generation. The findings indicate that the introduction of a separate bin for source-separated waste may result in a behavioral shift that increases total waste generation rather than encouraging waste minimization. This behavioral shift raises concerns about the effectiveness of such collection methods in meeting resource conservation targets and questions the environmental benefits of extending more convenient waste separation methods. Overall, the conclusion is that the bag system may be more effective in maintaining lower contamination levels and reducing total waste generation.

To address this issue, more sophisticated strategies based on behavior modification, education, and system redesign are required. Understanding these behavioral responses is critical for developing more effective waste management policies that encourage waste reduction and truly sustainable consumption patterns. Further research is needed to better understand these dynamics and develop strategies to mitigate the circular economy rebound effect, ensuring that collection methods contribute to waste reduction rather than unintentionally increasing overall waste generation.

Chapter 2

Recycling Gains and Material Losses: A Panel Analysis of Household Waste Trends in a Decade of Disruption

2.1 Introduction

The COVID-19 pandemic fundamentally disrupted societies worldwide. Although the acute phase of the pandemic has ended, its long-term effects remain evident. The emergency measures introduced to contain the virus, including curfews, school closures, and travel bans, and the longer effects of the pandemic (e.g., fiscal and monetary policy challenges) have significantly altered social behavior, economic activity, and consumption patterns (Behera, 2021; Maró et al., 2025; Zwanka and Buff, 2021). These economic and social problems and changes, while necessary for public health, have also affected environmental outcomes, particularly in terms of waste generation, and not necessarily in a positive way (Liang et al., 2021; Sarkodie and Owusu, 2021).

Nevertheless, several studies have indicated that consumption may have increased during the pandemic. Concerns over the prolonged impact of COVID-19 prompted individuals to stockpile food supplies (Amaral et al., 2022; Naughton, 2020), while increased stress and sleep disturbances triggered impulsive purchasing behavior, often driven by boredom (Deng et al., 2020; Yu et al., 2022). Collaborative consumption and online shopping have increased significantly as

consumers have turned to digital solutions and platforms – habits that many intend to retain even after the pandemic (de Medeiros et al., 2021). In some regions, consumer focus shifted toward essential goods such as staple foods, medicines, and hygiene products (Aday and Aday, 2020; Choo and Rajkumar, 2020). These observations highlight the significant and substantial influence of the pandemic on consumer behavior, with implications that extend beyond the short term and may persist well into long-term changes.

However, shifts and changes in consumer behavior are significant not only from economic and social perspective, but they are also important from an environmental perspective. The surge in demand for disposable masks, gloves and health-related products has the potential to increase the amount of waste generated, placing additional pressure on existing waste management systems (Adelodun et al., 2021). Furthermore, the rise of online shopping and the widespread use of single-use packaging has exacerbated, particularly in relation to plastic waste (Aggarwal, 2021). On a more positive note, the pandemic has made people aware of the importance of environmental protection and sustainability, potentially fostering greater ecological consciousness (Brontowiyono, 2021; Ranjbari et al., 2021; Vila and Costa, 2024). This could increase the willingness to participate in selective collection and encourage more conscious consumption behaviors, potentially resulting in higher recycling rates or even reductions in overall waste generation.

Assessing the impact of the current era on both waste generation and environmental awareness is therefore essential for addressing immediate as well as long-term sustainability challenges. Although the literature on this topic is extensive (Adelodun et al., 2021; Yoon et al., 2021; Zhao et al., 2022), most studies adopt a narrow approach and focus, often examining only isolated aspects of the impact of the pandemic, such as changes and shifts in recycling rates or the volume of specific types of waste like medical or hazardous waste (Yoon et al., 2021; Luney and Little, 2021; Adelodun et al., 2021). Few studies concurrently evaluate changes in household selective and non-selective waste, incorporate relevant microeconomic indicators that influence consumption patterns (Mahyari et al., 2022; Filho et al., 2022, 2021), or typically focus only on the national or regional level. The multifaceted nature of the issue requires a more integrated approach than what such fragmented research can provide. Thus, the primary aim of the research is to investigate how recent years influenced household waste generation behaviors in Hungary, with a specific focus

on both selective (recyclable) and non-selective (mixed) waste across different types of municipalities. The study also examines whether the pandemic catalyzed more sustainable waste management practices or exacerbated environmental degradation.

This study introduces several innovative and unique contributions to existing literature. First, it is among the first and few large-scale empirical studies to analyze municipal-level panel data on waste generation over a 12-year period (2012–2023), including microeconomic variables like per capita income. Second, as it was mentioned, unlike most prior studies that only address one type of waste or focus on healthcare waste, this research investigates both selective and non-selective waste at the household level, offering a holistic view of consumption and recycling behavior changes. Third, the use of the COVID-19 Stringency Index applies to a novel methodological framework using the Oxford Stringency Index to quantify government policy impacts and correlate them with shifts in waste generation. It is a refined approach to avoid statistical artifacts caused by annual data. Fourth, the study introduces and adapts the Excess-over-Expected Waste model, drawing from excess mortality methodologies, to estimate counterfactual scenarios of waste generation in the absence of the pandemic. This provides a robust counterfactual benchmark and allows for a clearer attribution of observed waste surges to pandemic-related behavioral shifts. The results could reveal a rebound effect in waste generation despite improved selective waste habits, highlighting that better recycling does not necessarily equate to less waste, which is critical for circular economy policymaking.

To achieve this, the article is structured as follows. The paper begins with an introduction to the environmental and behavioral shifts caused by COVID-19, followed by a literature review highlighting gaps in existing research. It then presents the data sources and research design, focusing on 640 Hungarian municipalities. The methodology section details advanced panel regression and excess-over-expected models using the COVID-19 Stringency Index. Results are discussed in terms of changes in waste generation, recycling behavior, and regional differences. The article concludes with implications for sustainability policy and waste management, noting the limitations of the study and outlining potential directions for future research.

2.1.1 Theoretical background

The COVID-19 pandemic has had profound social and environmental consequences that have changed consumption patterns, waste management practices, and broader sustainability efforts around the world. Government-imposed closures and restrictions have led to drastic changes in people's daily lives, affecting not only economic activities but also environmental behavior. While some of these changes have resulted in temporary environmental benefits, such as improved air quality due to reduced industrial activity and traffic, others have led to increased waste generation.

Health concerns have led to a dramatic increase in the demand for single-use plastics, resulting in a surge in plastic waste (Ikhlas et al., 2023). While this has helped reduce the spread of contamination, it has also created serious waste management challenges (Kumar et al., 2024; Mukherjee et al., 2024). The overburdening of waste management systems has caused problems worldwide, particularly in the management of infectious healthcare waste. The increased use of plastics due to the pandemic has highlighted the unsustainability of current linear waste management systems (Ganguly and Chakraborty, 2023). In some regions, the amount of healthcare waste increased several-fold during the pandemic, while processing capacity was insufficient to handle this increase (Ikhlas et al., 2023). Due to inadequate waste management, large quantities of these materials were released into the environment, particularly water and soil, where they degraded and released microplastics that entered marine life and the food chain, threatening human health and ecosystems (Sharma et al., 2020).

The epidemic has exposed weaknesses in waste management systems, particularly in developing countries (Vanapalli et al., 2021), where informal waste collectors play an important role in waste management but lack adequate protective equipment and labor rights (Pal and Kashyap, 2025). For informal waste collectors, the epidemic was not only a health crisis but also an economic crisis, as the closures meant that they were able to collect less recyclable material, severely affecting their livelihoods (Hemmesch et al., 2025). The social impacts of poor waste management went beyond direct health risks. Waste management workers were at increased risk of contamination, while their working conditions and wages did not improve, further exacerbating social inequal-

ities (Ferrara, 2025). Weaknesses in waste management infrastructure were also evident in developed countries, but the problem was particularly acute in developing countries. Waste collection systems were often compromised or eliminated altogether in some areas, leading to public health crises (Raoufi et al., 2025). Social trust in waste management systems declined, especially in areas where populations had previously relied on precarious infrastructure (Hemmesch et al., 2025).

The long-term environmental impact of plastic waste cannot be mitigated without the development of sustainable waste management solutions (Singh et al., 2024). The development of recyclable and biodegradable materials has come to the forefront as there is a growing demand for alternatives that can reduce the environmental footprint of single-use plastics (Najar et al., 2024). Transforming supply chains and waste management infrastructures can also be a key step towards sustainable development (Raoufi et al., 2025). The COVID-19 pandemic highlighted the vulnerability of global waste management systems. Overconsumption of single-use plastics and inadequate waste management infrastructures have created long-term challenges that require urgent solutions.

2.1.2 Changing consumption and waste generating patterns

The COVID-19 pandemic also had a significant impact on waste generation, with short-term and long-term consequences. In the short term, the pandemic led to an increase in household and medical waste worldwide due to the demand for single-use plastics and medical devices (Olawade et al., 2024; Fadaei, 2021). The pandemic generated approximately 1.6 million tons of waste per day, a significant proportion of which was single-use face masks (Christina et al., 2023). Global mask use was dominated in Asia, Europe and North America, generating tens of thousands of tons of plastic waste per day and posing significant environmental challenges (Sabol et al., 2022). According to research by Singh et al. (2020), the volume of COVID-19-related medical waste increased by up to 300% in some regions, and many waste treatment facilities lacked the capacity to handle the influx. Inadequate disposal of con-

taminated medical waste has increased public health risks and undermined efforts to control the virus.

In addition, during the first wave of the pandemic, fear and uncertainty often led to panic buying (Eva et al., 2021; Ralte et al., 2021), there was a global increase in the purchase of staple foods such as dry goods and canned goods (Nielsen, 2022). While this declined in the later stages of the pandemic, it was accompanied by a significant increase in online shopping due to restrictions and closures (McKinsey, 2020). Similar trends were observed in Hungary, where e-commerce sales reached record levels according to the Hungarian Central Statistical Office (KSH, 2021).

Prolonged closures and the spread of telecommuting have increased non-selective waste, especially household waste (Cai et al., 2021). The closure of offices, schools, and commercial establishments has shifted waste generation from commercial areas to residential areas, overwhelming household waste systems. In addition, the increased use of single-use plastics in food transportation, food packaging, and personal protective equipment (PPE) has placed a heavy burden on waste collection and processing infrastructure (Iimuro and Tabata, 2023).

Selective waste streams, especially recyclable plastics and cardboard, have also increased significantly due to changes in consumption patterns (Ammendolia et al., 2021). Filho et al. (2022) confirm these findings, showing how food distribution in Brazil has increased packaging waste, especially non-recyclable items such as plastic and paper/cardboard packaging. This trend was mirrored globally as consumers increasingly relied on courier services to deliver food and basic goods. The rapid growth of online shopping and food delivery services has contributed significantly to these challenges, particularly in urban areas where waste management systems were not prepared for the increase in packaging (Jumadewi et al., 2023; Lee and Lim, 2022).

Behavioral changes associated with the pandemic have exacerbated waste management challenges. Richter et al. (2021) and Vargas et al. (2023) found that while recycling rates increased in some areas, so did contamination levels, which also undermined the effectiveness of waste separation. In addition, socioeconomic factors played a critical role in the evolution of waste generation during the pandemic. Deng et al. (2020) showed that higher-income regions generated more waste overall, reflecting greater consumption capacity. The study in the city of Padang also showed that income levels played a signifi-

cant role in changes in waste generation and collection during the pandemic (Ruslinda et al., 2020).

While the existing literature provides valuable insights into the direct impacts of COVID-19 on waste systems and waste generation, it often focuses on isolated aspects without a holistic view of broader trends. As a result, the mechanisms behind the changes in behavior remain largely unexplored. Furthermore, most studies do not rely on comprehensive observational data, and very few studies have addressed the longer-term impacts of COVID-19. The present study aims to fill this gap.

2.1.3 New solid and household waste generation and recycling habits

The past few years offer a unique lens through which established theories of consumption, environmental sustainability, and waste generation can be (re-)examined. One foundational concept is the circular economy (CE) model, which challenges the traditional linear “take-make-dispose” approach by promoting waste minimization through reuse, recycling, and sustainable product design (Geisendorf and Pietrulla, 2018; Geissdoerfer et al., 2017).

The pandemic, however, introduced tensions between circularity and public health imperatives, such as the reliance on single-use plastics and disposable protective equipment. While the crisis temporarily disrupted the progress toward circular economy—and in this matter, circularity depends not only on systemic design but also on behavioral and infrastructural readiness—it also heightened awareness of environmental fragility, suggesting potential for behavioral shifts toward long-term sustainability (Kirchherr et al., 2017). Moreover, the resilience of circular systems is highly contingent on government intervention and institutional flexibility (e.g., waste separating systems), areas where most countries struggled during the pandemic (Rahmandoust et al., 2023). Despite these disruptions, the pandemic also served as a teachable moment for sustainability, bringing to the forefront the fragility of linear economic systems and encouraging shifts in both policy and consumer norms (Kanda and Kivimaa, 2020).

A second theoretical framework relates to consumer behavior theory, particularly the dual-process model of decision-making, which distinguishes between

fast, intuitive thinking (System 1) and slower, deliberative reasoning (System 2) (Costa et al., 2022; Evans and Stanovich, 2013; Frankish, 2010). During the pandemic, fear and uncertainty activated fast and emotional thinking, resulting in impulsive consumption behaviors such as panic buying and stockpiling (Costa et al., 2022; Prentice et al., 2022). These behaviors were further reinforced by media narratives. At the same time, lockdowns and increased time spent at home may have encouraged more deliberate, slow and rational behaviors, such as improved waste sorting and recycling. Some authors (Bergado et al., 2021; Tripathi et al., 2020) extend this understanding by showing how health-framing and cognitive load influenced compliance with prosocial behaviors. This behavior has parallels in environmental contexts. This duality explains why pandemic-era waste patterns were simultaneously chaotic and adaptive.

The COVID-19 pandemic has had profound social and environmental consequences that have changed consumption patterns, waste management practices, and broader sustainability efforts globally. Government-enforced lockdowns and restrictions brought significant disruptions to daily life, influencing not only economic activity but also environmental behavior. While some of these changes yielded temporary environmental benefits, such as improved air quality due to reduced industrial operations and traffic (Rodríguez-Urrego and Rodríguez-Urrego, 2020), others have led to increased consumption and waste generation. During the initial first wave of the pandemic, widespread fear and uncertainty often led to panic buying (Eva et al., 2021; Islam et al., 2021), leading to a global increase in the purchase of staple items such as dry and canned goods (Norris et al., 2021; Prentice et al., 2022). Although this behavior diminished in the later stages of the pandemic, it was accompanied by a significant increase in online shopping, driven by lockdowns and closures; thus, e-commerce sales reached unprecedented levels (Arora et al., 2020; Bhatti et al., 2020).

Health-related concerns drove a sharp increase in the use of single-use plastics, resulting in a substantial increase in plastic waste (Vanapalli et al., 2021; Wibowo et al., 2024). Although these measures helped to reduce the spread of contamination risk, they also created serious waste management challenges (Hantoko et al., 2021; Sarkodie and Owusu, 2021). The overburdening of waste management systems has caused problems worldwide, particularly in the management of infectious healthcare waste, revealing the fragility of existing sys-

tems. The pandemic underscored the unsustainability of current linear waste management models, particularly due to the widespread use of disposable plastic materials (Ganguly and Chakraborty, 2024). In some areas, the amount of healthcare waste multiplied during the pandemic, outpacing the available processing capacity (Sarkodie and Owusu, 2021; Wibowo et al., 2024). As a result of inadequate waste management, large quantities of improperly disposed materials entered the environment, especially into water and soil, where they degraded into microplastics. These pollutants infiltrated aquatic ecosystems and food chains, posing serious threats to both human health and biodiversity (Sharma et al., 2020).

The pandemic revealed significant vulnerabilities in waste management systems, particularly in developing countries (Vanapalli et al., 2021). In these regions, informal waste collectors play a crucial role in waste management but often lack proper protective equipment and labor rights (Pal and Kashyap, 2025). For informal waste collectors, the pandemic represented not only a health crisis but also an economic one, as lockdowns reduced the availability of recyclable materials, severely affecting their income and livelihoods (Hemmesch et al., 2025). The social implications of inadequate waste management extended beyond direct health risks. Waste workers faced heightened exposure to contamination, while their working conditions and wages remained unchanged, further exacerbating existing social inequalities (Ferrara, 2025). Weaknesses in waste management infrastructure were also evident in developed countries, but the challenges were particularly more acute in developing countries. Waste collection services were often disrupted or discontinued entirely, triggering local public health crises (Raoufi et al., 2025). Public trust in waste management systems declined, particularly in communities that had already depended on fragile or informal infrastructure (Hemmesch et al., 2025).

The long-term environmental impacts of plastic waste cannot be addressed without the development and implementation of sustainable waste management solutions (Adelodun et al., 2021; Sarkodie and Owusu, 2021; Singh et al., 2025). The innovation and adoption of recyclable and biodegradable materials have gained momentum, driven by growing demand for alternatives that can reduce the environmental footprint of single-use plastics (Najar et al., 2024). Reforming and transforming supply chains and upgrading waste management infrastructures are also essential steps toward sustainable development goals (Raoufi et al., 2025). Ultimately, the COVID-19 pandemic highlighted the

vulnerability and fragility of global waste management systems, underscoring how overreliance on single-use plastics and inadequate infrastructure have created persistent environmental and societal challenges that demand urgent and systemic solutions.

2.2 Data and research design

The data employed in this analysis originate from the Hungarian Central Statistical Office (Hungarian Central Statistical Office, 2025a), specifically from the Statinfo and T-STAR/TIMEA databases. The dataset possesses both temporal and spatial dimensions, forming a balanced panel structure that enables the investigation of short- and long-term trends in household waste generation.

The observational period spans from 2012 to 2023 on an annual basis and includes data from 640 municipalities across Hungary. Sample selection was guided by data availability and quality considerations. Municipalities with fewer than 2,000 inhabitants were excluded due to frequent data gaps and documentation inconsistencies, which could have undermined the reliability and robustness of the analysis.

To ensure representativeness and capture heterogeneity in waste generation behaviors, the final sample comprises a diverse set of urban and rural municipalities, stratified by geographic region and settlement size. Given that waste generation is closely associated with economic factors, particularly household income levels (Bandara et al., 2007; Khan et al., 2016), the analysis incorporates per capita taxable income at the municipal level as a key explanatory variable. Descriptive statistics for the main variables are provided in Table 2.1.

Table 2.1: Descriptive statistics of the dataset

Variable	Obs.	Mean	St. dev.
Population (capita)	7,660	12,203.15	68,676.19
Taxable income (1000 HUF/capita/year)	7,660	1,219.82	604.78
Non-selective waste (kg/capita/year)	7,660	196.68	63.58
Selective waste (kg/capita/year)	7,660	6.67	16.06

These significant differences can be attributed to the fact that although the Waste Framework Directive (2008/98/EC), which requires the establishment of separate waste collection systems across the European Union, came into force in 2008, Member States were given until January 1, 2015, to implement such systems. As a result, between 2012 and 2015, several smaller municipalities in Hungary had yet to introduce separate waste collection.

Table 2.2 summarizes the composition of the sample, using the categorization principles most applied by the Hungarian Central Statistical Office. The 640 Hungarian municipalities included in the sample exhibit considerable heterogeneity, enabling an analysis that spans settlements of varying sizes and economic conditions.

Table 2.2: Settlement type distribution

Settlement type (population size)	Count	Percentage
Small settlement ($\leq 10,000$)	482	75.31%
Medium-sized town (10,001–50,000)	138	21.56%
Large town (50,001–100,000)	11	1.72%
County seats and major cities ($> 100,000$)	8	1.25%
Capital (Budapest) (Special case)	1	0.16%
Total	640	100.00%

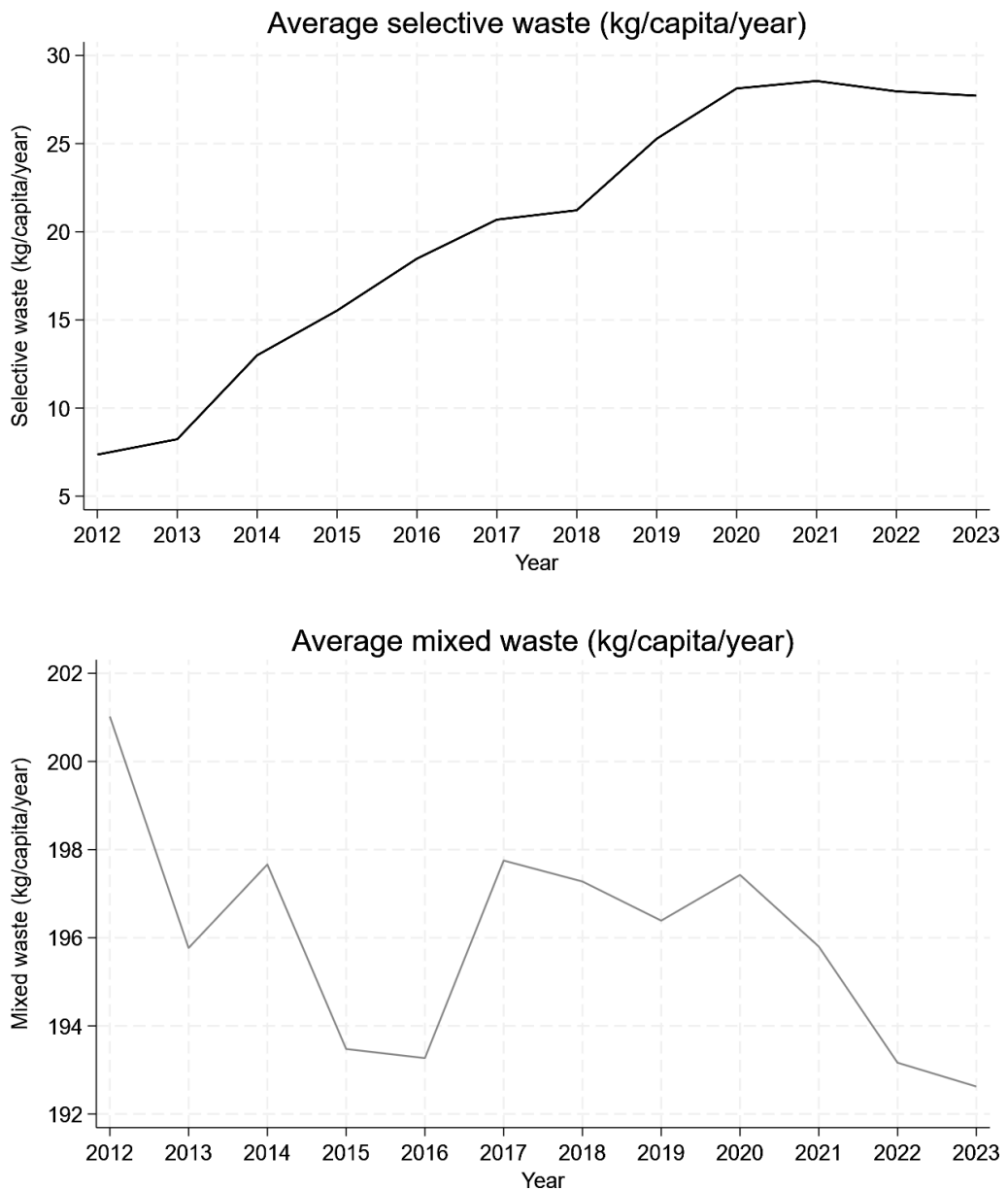
Most of the sample consists of small settlements with fewer than 10,000 inhabitants, representing 75.31% of the total sample. Medium-sized towns, with populations between 10,001 and 50,000, make up 21.56%. Municipalities with fewer than 2,000 inhabitants account for 14.06%, while those with populations of 50,001 or more comprise only 3.13%. Budapest, the capital city of Hungary, is treated as a special case within the sample.

The analysis of aggregated national per-capita waste data from 640 municipalities reveals distinct trends in selective and non-selective waste generation between 2012 and 2023. The developments are illustrated in Figure 2.1.

The volume of selectively collected waste steadily increased from 2012 to 2019, and this upward trend persisted throughout the COVID-19 period. The peak was reached in 2021. Although a slight decline followed, post-pandemic levels have consistently remained above those recorded in 2019. In contrast, the

volume of non-selectively collected waste exhibited year-to-year fluctuations between 2012 and 2019. A noticeable increase occurred during 2020–2021, likely linked to the pandemic; however, this surge proved temporary, as a significant decline was observed in the years following the pandemic.

Figure 2.1: Amount of waste (kg) generated and collected separately in Hungary



Assessing the impact of the COVID-19 pandemic is challenging due to the annual structure of the available data. Therefore, to assess the impact

of the pandemic, the COVID-19 Stringency Index was employed. This index is a composite, daily indicator that quantifies the strictness of government-imposed measures, such as school closures, stay-at-home mandates, bans on public gatherings, and mobility restrictions. It is based on a comprehensive database developed by the Blavatnik School of Government at the University of Oxford and is widely recognized for measuring the political and social intensity of the COVID-19 response (Hale et al., 2021).

Table 2.3: Description of the variables

Variable	Explanation	Source
Dependent variables		
Selective_waste	Annual selective waste per capita (kg/person/year)	Statinfo (KSH)
Mixed_waste	Annual non-selective (mixed) waste per capita (kg/person/year)	Statinfo (KSH)
Total_waste	Annual total household waste per capita (kg/person/year)	Statinfo (KSH)
Recycling_rate	Share of selectively collected waste compared to total waste (%)	Statinfo (KSH)
Independent variables		
Covid_Stringency	Index measuring the strictness of COVID-19 measures	Blavatnik School of Government (University of Oxford)
Taxable_income	Annual taxable income per capita (thousand HUF/person/year)	T-STAR/TIMEA (KSH)
Adult	Share of population aged 18–59 (% of total population)	T-STAR/TIMEA (KSH)
Elderly	Share of population aged 60 and above (% of total population)	T-STAR/TIMEA (KSH)
Internet	Number of internet subscriptions per 100 inhabitants	T-STAR/TIMEA (KSH)
Cars	Number of passenger cars per 100 inhabitants	T-STAR/TIMEA (KSH)
Pensioners	Share of old-age pensioners in the total population (%)	T-STAR/TIMEA (KSH)
Educated_workers	Share of job seekers with higher education (% of total population)	T-STAR/TIMEA (KSH)
Employment	Share of job seekers registered for more than 180 days (% of total population)	T-STAR/TIMEA (KSH)

Given the availability of annual panel data, daily Stringency Index values were aggregated to the yearly level using a simple arithmetic average. As epidemiological policy implementation in Hungary was uniform nationwide, the index assumes the same value for all municipalities each year. In addition, several control variables were incorporated into the dataset to strengthen the explanatory power of the model and account for potential confounding effects. Including these controls is a standard and widely accepted practice in quantitative economic research (see e.g., Bakó et al., 2025, Démurger, 2001, Kyriacou et al., 2019). However, the primary objective of this study is not to evaluate the individual effects of these control variables. Table 2.3 provides a detailed description of all variables used in the analysis.

2.3 Methodology

This study employs panel regression models with two-way fixed effects (TWFE) (Correia et al., 2020; Imai and Kim, 2021) to investigate the impact of recent years on waste generation, with particular emphasis on the quantities of selective and non-selective waste. The panel regression approach facilitates the control of municipality-level fixed effects and time-specific macroeconomic shocks, thereby enabling more accurate estimation of the relationships among variables. This methodology is especially advantageous when working with large panel datasets, as highlighted by Correia et al. (2020), since it mitigates bias arising from unobserved time-invariant municipal characteristics and permits accurate assessment of the dynamic effects of COVID-19 on waste production.

Model estimation was conducted using the `reghdfe` command in Stata, which efficiently estimates two-way fixed effects (municipality and temporal fixed effects) while avoiding the computational burden of including a large number of dummy variables explicitly (Clarke and Tapia-Schythe, 2021; Correia et al., 2020). This method ensures comprehensive accounting for both spatial (settlement-specific) and temporal heterogeneity and provides robust standard errors. The municipality fixed effects control for time-invariant factors such as institutional differences and baseline regulatory frameworks, whereas time fixed effects account for broader macroeconomic shocks and structural

policy shifts, ensuring that the estimated impact of COVID-19 is not biased by unrelated time trends.

However, the structure of the available data required the application of alternative modelling strategies to better capture the effect of previous years. These include a fixed-effects panel model with a quadratic time trend (Angrist and Pischke, 2009), an interaction model incorporating income levels to assess heterogeneous effects across socioeconomic strata (Gershoff et al., 2007; Hong et al., 2019), and an expected value-based estimation procedure adapted from methodologies commonly used in excess mortality studies (Beaney et al., 2020; Kontis et al., 2020).

Model 1: Panel regression with quadratic trend and fixed effects

Model 1 assumes that municipal waste generation follows a non-linear time trend, incorporating additional fixed effects at the municipal level. The inclusion of a quadratic time trend enables the model to capture annual variation without the need for year-specific dummy variables. This specification avoids collinearity between the COVID-19 variable and time effects, since the national-level nature of the Stringency Index varies only over time and not across municipalities. As such, the model facilitates estimation of the underlying temporal trend based on pre-pandemic data and allows for the derivation of the counterfactual (without the pandemic) values for the COVID-19 period.

Municipal fixed effects are included to control unobserved, time-invariant characteristics specific to each municipality, such as infrastructure, waste collection systems, and levels of environmental awareness. These fixed effects help eliminate bias from factors that could otherwise distort the estimated effects of COVID-19. Additionally, the model includes income as a key explanatory variable, which has been identified as a determining factor in the volume and composition of consumption. The Stringency Index, which quantifies the severity of governmental restrictions during the pandemic, is also incorporated as a proxy for behavioral changes in households – such as shifts in mobility and consumption patterns – that likely influenced waste generation dynamics.

The baseline regression model is specified as follows (Equation 2.1):

$$Y_{it} = \alpha + \beta_1 \text{Trend}_t + \beta_2 \text{Trend}_t^2 + \beta_3 \text{Stringency}_t + \mu_i + u_{it} \quad (2.1)$$

where Y_{it} denotes the amount of waste generated, measured either as total municipal waste per capita (in kg/capita/year) or as the recycling rate (i.e., the proportion of selective waste relative to total waste) for municipality i at time t . The variables Trend_t and Trend_t^2 capture linear and quadratic components of the time trend, respectively, Stringency_t represents the national COVID-19 Stringency Index, μ_i denotes municipality-specified fixed effects, and u_{it} is the idiosyncratic error term.

In an extended model specification (Equation 2.2), additional socio-economic control variables are incorporated to account for demographic characteristics and infrastructural differences across municipalities:

$$\begin{aligned}
Y_{it} = & \alpha + \beta_1 \text{Trend}_t + \beta_2 \text{Trend}_t^2 + \beta_3 \text{Stringency}_t + \beta_4 \text{Income}_{it} + \beta_5 \text{Adult}_{it} + \\
& \beta_6 \text{Educated_workers}_{it} + \beta_7 \text{Internet}_{it} + \beta_8 \text{Cars}_{it} + \beta_9 \text{Pensioners}_{it} + \\
& \beta_{10} \text{Elderly}_{it} + \beta_{11} \text{Employment}_{it} + \mu_i + u_{it}
\end{aligned} \tag{2.2}$$

where the additional variables are included to represent demographic and infrastructural characteristics (see Table 2.3).

Model 2: Excess over expected

This approach builds on the methodologies developed in excess mortality research during the era of COVID-19, aiming to estimate counterfactual waste generation levels in the absence of the pandemic (see e.g., Chandra et al., 2024). To predict expected waste generation, both the baseline and extended regression models are re-estimated using data from the 2012–2019 period. These models are designed to capture the underlying temporal dynamics and socio-economic determinants of waste generation prior to the onset of the COVID-19 outbreak.

Using the predicted values $\widehat{Y}_{it}^{\text{expected}}$ for the 2020–2023 period, excess waste generation is calculated as in Equation 2.3:

$$\text{Excess}_{it} = Y_{it}^{\text{observed}} - \widehat{Y}_{it}^{\text{expected}} \tag{2.3}$$

Finally, the estimated excess values are regressed on the same set of explanatory variables that were used to generate the expected values: time trends in the baseline model, and both time trends and socioeconomic as well as infrastructural variables in the extended specification.

Heterogeneity analysis

The impact of the COVID-19 pandemic was unlikely to be uniform across all municipalities; rather, it may have varied depending on the socioeconomic conditions and specific local characteristics of the municipalities. It is therefore essential to explore how the effects differ along social and geographic dimensions. Analyzing such heterogeneity not only enhances the accuracy of empirical assessments but also enables more targeted and effective policy interventions by identifying which population groups or regions were most affected.

Given that the effect of a particular intervention or external shock (in this case the COVID-19 pandemic) may differ substantially between rural and urban populations due to factors such as the size of the settlement, economic development, or demographic composition, it is appropriate to consider the concept of the heterogeneous treatment effects (HTE) (Wager and Athey, 2018; Xie et al., 2012). For instance, households in smaller municipalities may face practical barriers to adopting selective waste collection due to insufficient infrastructure or limited access. In contrast, residents of large urban areas are more likely to benefit from convenient access to waste sorting and collection services. Therefore, the impact of the pandemic on waste generation habits can vary significantly across municipalities with differing characteristics. Consequently, the study also investigates the effects of COVID-related restrictions across distinct types of settlements.

A range of statistical methods are available to empirically identify heterogeneous treatment effects. Based on the structure of the data, two interaction models were estimated separately, each including a different interaction term. This approach enables an analysis of how infrastructural, developmental, and other municipal-level differences shaped waste generation patterns throughout the course of the pandemic. The two interaction models were estimated within a unified regression framework, which can be described as follows (Equation 2.4):

$$Waste_{it} = \alpha + \beta_1 \text{Interaction}_{it} + \beta_2 \text{Income}_{it} + \lambda_t + \mu_i + u_{it} \quad (2.4)$$

where Interaction_{it} denotes the interaction term between the COVID-19 Stringency Index and the type of settlement ($\text{Stringency}_t \times \text{Settlement_type}_i$). λ_t represents the year fixed effects. All other variables retain their definitions provided in the previous model specifications.

This analytical approach contributes to a more nuanced and detailed exploration of the relationship between the pandemic and waste generation. While previous studies have typically analyzed the impact of recent years on waste generation at national or regional level (if addressed at all), the methodology applied here allows for the identification of differences across municipal typologies. By examining interaction effects, the analysis offers a more accurate depiction of the divergent waste generation dynamics observed between urban and rural areas.

2.4 Results and discussion

2.4.1 Results of the panel regression

First, panel regression models are estimated to evaluate the effects of the COVID-19 pandemic on various waste management outcomes, including selective waste generation, non-selective waste generation, total municipal waste generation, and the recycling rate. These models incorporate quadratic time trends and the national COVID-19 Stringency Index, are further augmented by socioeconomic control variables and municipality fixed effects. The results of the initial model are summarized in Table 2.4.

The estimated coefficients indicate that stricter pandemic-related restrictions were associated with an increase in both selective and non-selective waste generation per capita. Specifically, the COVID-19 Stringency Index exhibits a positive and statistically significant association with mixed waste generation (0.106 kg/capita/year) and selective waste generation (0.017 kg/capita/year), suggesting that periods of more stringent government measures coincided with increased accumulation of waste in both categories. Importantly, while the increase in selective waste is a positive outcome, the rise in non-selective waste did not occur in isolation; rather, it contributed to a statistically significant overall increase in total municipal waste generation (0.123 kg/capita/year). This finding implies that the pandemic placed additional pressure on local waste management systems by amplifying the total volume of waste produced.

Table 2.4: Panel regression results with time trends

Variable	Mixed	Selective	Total	Recycling Rate
COVID Stringency	0.106*** (0.019)	0.017*** (0.004)	0.123*** (0.020)	0.00003 (0.00001)
Trend	-2.240*** (0.773)	1.375*** (0.144)	-0.865 (0.777)	0.006*** (0.0006)
Trend ²	0.158*** (0.059)	-0.048*** (0.009)	0.111* (0.059)	-0.002*** (0.0004)
Constant	201.315*** (1.923)	0.944** (0.476)	202.259*** (1.947)	0.0053*** (0.0018)
Observations	7,660	7,660	7,660	7,660
R^2	0.681	0.730	0.698	0.737

Notes: Robust standard errors clustered at the settlement level are reported in parentheses. Waste indicators are measured in kilograms, while the recycling rate is presented as a percentage.

In contrast, the recycling rate does not show a statistically significant relationship with the COVID-19 Stringency Index. Although the absolute quantity of selectively collected waste increased, this growth was proportional to the rise in total waste, resulting in a relatively stable recycling rate. This outcome suggests that the pandemic did not meaningfully alter recycling behavior or the effectiveness of selective collection systems during the period under study. Overall, the results indicate that the COVID-19 pandemic significantly increased the amount of both selective and non-selective municipal waste. Based on the estimated coefficients, the average COVID-19 Stringency Index of 56.01 in Hungary during 2020 is associated with an increase of approximately 5.94 kg of mixed waste and 0.95 kg of selectively collected waste per capita per year. In total, this corresponds to an estimated additional 6.89 kg of municipal solid waste generated per capita during the pandemic period in 2020.

The extended regression model yielded results that are broadly consistent with the baseline specification but offer greater nuance (see Table 2.5). The COVID-19 Stringency Index remained positively associated with selective waste generation (0.016 kg/capita/year), mixed waste generation (0.098 kg/capita/year), and total waste generation (0.113 kg/capita/year). Although the estimated coefficients are marginally lower than those obtained from the

baseline model, the effects remain substantively meaningful, suggesting that more stringent pandemic-related restrictions were consistently linked to increased waste generation. As in the baseline specification, the recycling rate did not exhibit a statistically significant association with the Stringency Index; however, the observed trend was slightly negative.

Based on these estimates, an average COVID-19 Stringency Index of 56.01 corresponds to an additional 8.74 kg of selectively collected waste, 0.89 kg of mixed waste, and 9.63 kg of total municipal waste generated per capita. The predicted change in the recycling rate remains negligible. Nevertheless, the results suggest that although selective waste generation increased during the pandemic, it was accompanied by a concurrent increase in mixed waste generation, ultimately leading to an overall rise in total municipal waste. While the recycling rate remained relatively stable, the significant increase in per capita waste generation represents a negative environmental outcome that underscores the broader pressure placed on municipal waste management systems during the pandemic period.

This pattern is supported by literature (Brontowiyono, 2021; Ranjbari et al., 2021). The transition to remote work increased the time spent at home, potentially enhancing attention to selective waste collection. Changes in consumer behavior, such as reduced purchases of non-essential goods and more sustainable consumption habits, also contributed to shifts in waste generation patterns. However, increased waste volumes, even selectively collected, strain municipal systems, especially in regions lacking processing capacity (Adelodun et al., 2021; Sarkodie and Owusu, 2021). The stability in the recycling rate despite higher selective waste volumes implies that improved participation may not have been accompanied by improvements in waste sorting accuracy or system efficiency. This echoes the rebound effect described by Maier et al. (2023), whereby individuals engage in higher consumption under the perception that waste is being handled sustainably, which paradoxically undermines environmental gains.

Table 2.5: Panel regression results with time trends and additional controls

Variable	Mixed	Selective	Total	Recycling Rate
COVID Stringency	0.098 ^{***} (0.024)	0.016 ^{**} (0.007)	0.113 ^{***} (0.068)	0.00001 (0.00001)
Income (z-score)	8.932 ^{***} (2.566)	0.174 (0.160)	9.105 ^{***} (2.644)	-0.001 (0.007)
Trend	-1.065 (0.490)	1.269 ^{***} (0.347)	-0.420 (0.524)	0.062 ^{***} (0.009)
Trend ²	-0.173 ^{**} (0.083)	-0.044 ^{**} (0.019)	-0.217 ^{**} (0.090)	-0.002 ^{***} (0.0004)
Percentage of adults	-39.715 (127.936)	-40.214 (34.979)	-79.929 (131.473)	-0.078 (0.130)
Percentage of elderly	-159.533 (117.036)	36.704 (35.308)	-122.830 (122.054)	0.124 (0.414)
Internet subscription	-25.111 ^{***} (9.556)	-1.367 (1.320)	-26.478 ^{***} (9.795)	-0.005 (0.005)
Car ownership rate	67.304 ^{**} (26.085)	6.422 (6.422)	73.726 ^{**} (29.063)	0.084 (0.074)
Pensioners	-119.885 (79.625)	44.274 (29.232)	-75.610 (84.052)	0.074 (0.278)
Educated workers	574.481 (871.752)	-174.90 (312.881)	399.570 (903.000)	-0.643 (3.400)
Local employment rate	138.530 [*] (77.033)	25.995 (28.697)	164.526 (79.232)	0.067 (0.090)
Constant	279.918 ^{***} (96.823)	4.120 (26.404)	284.038 ^{***} (98.155)	0.208 (0.294)
Observations	7,660	7,660	7,660	7,660
R^2	0.688	0.734	0.741	0.739

Notes: Waste indicators are measured in kilograms, while the recycling rate is expressed as a percentage. Robust standard errors clustered at the settlement level are reported in parentheses.

2.4.2 Excess-over-expected method

In the second stage of the analysis, an excess-over-expected framework was applied. Expected waste generation was first estimated using fixed effects panel regressions with quadratic time trends, based on the data from the pre-pandemic period (2012-2019). The difference between the actual observed values and the predicted counterfactual values for the 2020–2023 pe-

riod was then calculated to derive measures of excess waste generation. These excess values were regressed on the COVID-19 Stringency Index to evaluate how pandemic-related restrictions contributed to the deviations from expected waste generation. The results of the initial model are presented in Table 2.6.

The regression results on excess waste generation reveal a strong and positive relationship between the COVID-19 Stringency Index and the volume of excess waste. Specifically, a one-unit increase in the Stringency Index is linked to an additional 0.068 kg of selectively collected waste, 0.354 kg of mixed waste, and 0.421 kg of total waste per capita per year. These results suggest that stricter pandemic-related restrictions led significantly to substantial increases in both selective and non-selective waste streams, with the most pronounced effect observed in total waste generation.

The recycling rate also exhibited a small but statistically significant positive association with the Stringency Index, suggesting that periods of more restrictive measures were associated with modest improvements in recycling performance. However, this increase was relatively limited and did not offset the overall rise in total waste generation. Based on the estimated coefficients, an average COVID-19 Stringency Index of 56.01 in Hungary corresponds to approximately 3.81 kg of excess selectively collected waste, 19.82 kg of excess mixed waste, and a total of 23.63 kg of additional municipal waste generated per capita on an annual basis.

Table 2.6: Panel regression results on excess waste estimated based on time trends (2020–2023)

Variable	Mixed	Selective	Total	Recycling Rate
COVID Stringency	0.354 ^{***} (0.021)	0.068 ^{***} (0.004)	0.421 ^{***} (0.022)	0.0002 ^{***} (0.00017)
Constant	-22.266 ^{***} (0.612)	-4.977 ^{***} (0.124)	-27.242 ^{***} (0.631)	-0.145 ^{***} (0.004)
Observations	2,540	2,540	2,540	2,540
R^2	0.906	0.962	0.914	0.962

Note: Waste indicators are measured in kilograms, while the recycling rate is expressed as a percentage.

In the second model specification, the excess values were estimated from pre-pandemic quadratic time trends alongside additional socioeconomic and infrastructural controls. These included indicators of income, age structure, internet access, car ownership, the proportion of pensioners, education level, and local employment rates. The results are presented in Table 2.7.

The findings confirm a statistically significant and positive effect of the COVID-19 Stringency Index on total waste excess (0.469 kg/capita in a year). This suggests that even after accounting for local demographic and infrastructural characteristics, stricter governmental restrictions were associated with a notable increase in municipal waste. Crucially, the model also reveals a divergence between selective and mixed waste patterns. The excess in selectively collected waste remained significantly positive (0.588 kg/capita/year), whereas the excess in mixed waste became negative (-0.119 kg/capita/year). This indicates that, although the pandemic led to an overall increase in total municipal waste, part of this rise can be attributed to a compositional shift from mixed to selectively collected waste streams. Based on these estimated coefficients, an average COVID-19 Stringency Index of 56.01 in 2020 would correspond to approximately 32.94 kg of excess selective waste, a reduction of 6.66 kg in mixed waste, and a net increase of 26.27 kg in total municipal waste per capita on an annual basis.

According to the literature (Ranjbari et al., 2021; Vila and Costa, 2024), the individuals' willingness to adopt sustainable behaviors increased during the pandemic, as the crisis underscored the relevance of environmental protection in enhancing societal resilience. Consequently, engagement in environmentally responsible practices – such as waste reduction and selective waste collection – increased markedly. Supporting this, Contreras-Contreras et al. (2023) and Tolppanen et al. (2023) found that the pandemic triggered a broader paradigm shift, fostering stronger support for sustainability initiatives and reinforcing the connection between well-being and the pursuit of sustainable lifestyles, potentially promoting long-term behavioral change. However, this transition toward greater environmental consciousness has also had unintended negative consequences, particularly due to the rise in online purchasing. While digital consumption increased rapidly during the pandemic, it did not recede to pre-pandemic levels afterward. A typical e-commerce delivery may contain up to seven different types of packaging materials, many of which are challenging

to recycle. Furthermore, online shopping can generate up to 4.8 times more packaging waste than traditional brick-and-mortar retail (Kim et al., 2022).

Table 2.7: Panel regression results on excess waste estimated based on time trends and additional controls (2020–2023)

Variable	Mixed	Selective	Total	Recycling Rate
COVID Stringency	-0.119** (0.056)	0.059*** (0.009)	-0.060 (0.057)	0.0001** (0.0004)
Income (z-score)	-18.290*** (2.493)	0.309 (0.356)	-17.98*** (2.520)	0.0035** (0.0014)
Percentage of adults	-516.460** (222.218)	59.621* (31.088)	-456.838** (223.035)	0.010 (0.137)
Percentage of elderly	-478.558* (258.187)	-112.433*** (27.359)	-590.991** (262.522)	-0.334*** (0.009)
Internet subscription	38.579** (17.849)	-2.162 (2.453)	36.417* (18.025)	0.014 (0.009)
Car ownership rate	-45.832 (47.855)	3.314 (7.317)	-42.518 (51.399)	-0.351 (0.023)
Pensioners	275.037 (171.221)	-46.297** (19.595)	228.740 (173.040)	-0.110 (0.063)
Educated workers	-587.654 (906.298)	634.028*** (169.590)	46.373 (913.420)	2.178*** (0.640)
Local employment rate	-172.344 (119.616)	54.209 (57.139)	-118.130 (150.780)	0.194 (0.169)
Constant	371.899** (163.372)	-1.139 (24.321)	370.76** (166.350)	0.051 (0.102)
Observations	2,540	2,540	2,540	2,540
R^2	0.913	0.963	0.913	0.963

Note: Waste indicators are measured in kilograms, while the recycling rate is expressed as a percentage.

Further empirical evidence (Svatosova, 2022; Mahpour et al., 2024; Adibfar et al., 2022) suggests that a significant share of consumers continue to plan and make purchases online even after the acute phase of the pandemic. Official statistics from Hungarian Central Statistical Office (2025a) show that the share of individuals making online purchases within a three-month period rose

from 35% in 2019 to 61% in 2022 (and 61.7% in 2024). These trends suggest a lasting shift in consumer behavior. The proportion of online purchases, which are typically associated with higher volumes of packaging waste, has not returned to pre-pandemic levels. Simultaneously, offline (in-store) shopping has also rebounded following the lifting of COVID-related restrictions, further contributing to the overall increase in waste generation. Although much of this waste is now being directed into selective collection systems, the environmental implications remain concerning. Public understanding of proper selective waste disposal practices remains limited. As a result, a substantial portion of the waste placed in recycling bins may be non-recyclable. This significantly undermines the effectiveness of selective waste collection systems and reduces the actual recovery of recyclable materials.

2.4.3 Differences in waste generation across municipalities

The 640 municipalities included in the analysis exhibit substantial variation in terms of development and (waste management) infrastructure. In the smallest municipalities, dedicated waste collection systems were in some cases absent until as late as 2015. Moreover, the implementation of waste collection infrastructure was not uniform across all municipalities. In the largest cities, the so-called double-bin system dominated, whereby households were provided with separate containers for paper and plastic waste, while landfills and communal collection points ("islands") continued to operate for extended periods. In contrast, smaller municipalities typically implemented either communal collection islands or a door-to-door bag-based collection system. In the latter, residents received transparent bags for sorting different waste types, which were then collected at scheduled intervals. Given the significant differences in the design and effectiveness of waste management infrastructures and collection systems, the analysis examines whether COVID-related restrictions had different impacts across different settlement types.

To assess potential heterogeneity in the effects of the pandemic, municipalities were categorized into three groups based on population size: settlements with fewer than 10,000 inhabitants were classified as rural areas, those with 10,001 to 100,000 inhabitants as towns, and those exceeding 100,000 inhabi-

tants as major cities. This classification allows for the identification of distinct patterns in waste generation and policy responsiveness across settlement types. Estimation results based on interaction terms, using rural settlements as the reference category, are presented in Table 2.8.

The heterogeneity analysis reveals significant differences in how municipalities of varying sizes responded to pandemic-related restrictions. In this specification, interaction terms between the COVID-19 Stringency Index and settlement type categories were included to examine whether the impact of policy stringency varied across rural areas, towns, and major cities. Rural municipalities, defined as those with populations under 10,000, serve as the reference category, while the effects for towns and major cities are captured through corresponding interaction terms. The results suggest that COVID-19-related restrictions had negligible, or in some cases slightly adverse, effects on waste generation in rural areas. In contrast, the impacts were substantially more pronounced in urban municipalities. In towns, the Stringency Index was associated with an increase of 0.069 kg per capita in selectively collected waste and a 0.764 kg per capita rise in total mixed waste. The estimated effects were considerably larger in major cities, where selective waste generation increased by 0.274 kg and total waste by 2.628 kg per capita annually. While mixed waste generation showed a modest increase in rural areas (0.083 kg), it slightly declined in major cities (-0.111 kg per capita), indicating a possible and potential shift toward more effective waste separation practices in urban settings. A similar pattern was observed for the recycling rate, which declined marginally in villages but improved with increasing settlement size, rising in towns and cities relative to rural areas.

Table 2.8: Heterogeneity analysis across the municipalities (2012–2023)

COVID Stringency	Mixed	Selective	Total	Recycling Rate
Village (reference)	0.083 ^{***} (0.028)	-0.006 (0.070)	0.021 (0.074)	-0.00025 ^{**} (0.00009)
Towns	0.070 (0.056)	0.069 ^{***} (0.022)	0.764 ^{***} (0.226)	0.00052 ^{***} (0.00018)
Major Cities	-0.111 (0.116)	0.274 ^{***} (0.051)	2.628 ^{***} (0.502)	0.0016 ^{***} (0.00039)
Observations	7,660	7,660	7,660	7,660
R^2	0.688	0.736	0.743	0.770

Notes: The regression models included both quadratic time trends and additional socioeconomic control variables. Waste indicators are measured in kilograms, while the recycling rate is expressed as a percentage.

Using the average COVID-19 Stringency Index value recorded in Hungary in 2020 (56.01), the estimated pandemic-induced changes in per capita waste generation across different settlement types are as follows:

- Villages (rural areas): Mixed waste increased by 4.65 kg. The recycling rate declined minimally.
- Towns: Relative to villages, selective waste increased by 3.53 kg, total municipal waste rose by 42.79 kg per capita, and the recycling rate improved.
- Major cities: Compared to villages, selective waste increased by 15.35 kg, total municipal waste rose by 147.19 kg (and mixed waste decreased by 6.22 kg per capita). The recycling rate improved significantly, with a gain of 0.09 percentage points.

These findings underline the importance of accounting for heterogeneity in municipal responses to the pandemic. Urban areas experienced a markedly stronger response in terms of both the volume of waste generated and changes in recycling behavior. This may be attributed to higher levels of consumption and the greater availability and accessibility of selective waste collection. One potential explanation for this pattern is the widespread implementation of the

double-bin system, which was primarily adopted by municipalities with populations exceeding 50,000 (Struk, 2017). This system enhanced the efficiency and convenience of waste separation by providing residents with dedicated bins for paper and plastic waste. Additionally, the rapid expansion of e-commerce platforms and food delivery services during the pandemic disproportionately benefited larger urban areas, where such services became more accessible and widely used compared to smaller towns and rural settlements (Kim et al., 2022; Lee and Lim, 2022). As a result, urban residents were exposed to significantly higher volumes of packaging materials and single-use food containers, most of which were disposed of in selective waste bins. In contrast, rural municipalities, mirroring findings in the Global South (Adelodun et al., 2021; Pal and Kashyap, 2025), often lacked adequate infrastructure, leading to higher reliance on mixed disposal channels and lower recycling performance. These patterns also suggest that without equitable access to collection infrastructure, even well-intentioned behaviors may fail to translate into positive environmental outcomes, reinforcing environmental inequality as a latent dimension of pandemic resilience.

2.5 Conclusions

This study provides one of the first large-scale empirical investigations into how the COVID-19 pandemic affected municipal household waste generation and habits across Hungary. Using panel data from 640 municipalities and multiple econometric methods, the analysis captures a nuanced view of pandemic-era waste behavior. The findings reveal a consistent increase in both selective and total waste during periods of stricter COVID-19 restrictions, while the recycling rate remained largely unchanged. These results suggest that although recycling behaviors may have improved, the overall environmental impact was more ambiguous. The rise in total waste indicates that greater engagement in selective collection did not translate into waste minimization. Moreover, the variation between urban and rural areas, driven largely by differences in infrastructure and service availability, highlights the importance of localized approaches in waste management policy. The results support existing theories such as the circular rebound effect and dual-process consumer behavior mod-

els, which help explain the coexistence of pro-environmental intentions and increased material consumption.

Despite its methodological strengths, the study faces several limitations. First, waste composition data were not available at a granular level, which restricts deeper analysis of specific material flows (e.g., plastics vs. paper). Second, contamination rates within the selective stream could not be directly measured, which limits the assessment of recycling effectiveness. Third, behavioral variables, such as environmental awareness or perceived risk, were not included, as such data were not systematically available at the municipal level. Thus, future research could build on these findings by incorporating micro-level behavioral surveys to better capture consumer motivations and environmental attitudes during crisis periods. Studies with access to disaggregated waste fractions and contamination levels would allow for more precise assessments of recycling system performance. Additionally, exploring digital waste tracking systems and real-time policy feedback loops could improve the responsiveness of municipal waste governance, not only in pandemic contexts but also in preparation for future sustainability and climate resilience challenges.

Chapter 3

Behavioral Response to Convenience: A Natural Experiment on Door-to-Door Selective Waste Collection

3.1 Introduction

Over the past decade, significant transformations in waste management and recycling practices have been observed, fundamentally influencing public attitudes toward environmental sustainability. The global dissemination of selective waste collection systems has been accompanied by the development of waste management infrastructure and a heightened awareness of environmental issues (Abbas and Lamri, 2025; Boström, 2021). However, a circular economy rebound effect has also been documented in certain contexts (Metic and Pigosso, 2022; Mongo, 2021; Zink and Geyer, 2017), wherein the introduction of selective waste collection has paradoxically coincided with an increase in overall waste generation. This phenomenon has been interpreted as indicative of a behavioral response in which adequate waste management infrastructure is perceived by consumers as justification for increased consumption (Chen, 2021).

At the same time, the COVID-19 pandemic introduced unprecedented challenges to waste management systems. Extended periods of home confinement, the surge in online shopping, and the widespread use of personal protective

equipment (e.g., masks and gloves) were associated with significant shifts in both the quantity and composition of household waste (Patrício Silva et al., 2021). Although a reduction in overall municipal waste was associated with decreased economic activity, notable increases in selectively collected waste, particularly packaging materials, were reported (Benson et al., 2021; Lehmann et al., 2021). Additionally, heightened environmental awareness was observed during and after the era of pandemic, as individuals became increasingly engaged with sustainability-related behaviors (Ganguly and Chakraborty, 2021; Matiuk and Liobikienė, 2023).

Despite extensive research on household recycling behavior and waste separation practices (Derksen and Gartrell, 1993; Jenkins et al., 2003), limited empirical research has explored how behavioral responses to waste management infrastructure evolve under external shocks, such as public health crises. While previous studies have examined the effectiveness of selective waste collection systems under normal conditions, the potential for such infrastructure to induce unintended behavioral consequences during times of disruption remains underexplored. Moreover, while the circular economy rebound effect has been conceptualized theoretically (Lowe et al., 2024; Zink and Geyer, 2017), empirical assessments quantifying its manifestation in real-world municipal waste data remain scarce. This study addresses this gap by applying, for the first time to our knowledge, a quasi-experimental approach that exploits the COVID-19 pandemic as an exogenous shock to evaluate and isolate the behavioral and rebound effects of selective waste infrastructure under externally imposed constraints. The research provides evidence that infrastructure convenience can lead to an increase in total waste output, not just a shift in waste composition, underlining the importance of behavioral dynamics in policy evaluation.

Methodologically, the study employs a two-way fixed effects (TWFE) regression model based on a difference-in-differences (DiD) framework (Callaway and Sant’Anna, 2021; Goodman-Bacon, 2021) to assess the causal impact of door-to-door selective waste collection on household-level waste outcomes. This approach improves earlier correlational analyses by addressing concerns of self-selection and unobserved heterogeneity. Moreover, the study introduces and empirically tests the concept of the Perceived Disposal Ease Bias, contributing to the theoretical literature on behavioral distortions in environmental decision-making. The findings have clear implications for environmental

policy: while selective collection systems are effective in increasing recycling rates, they may also unintentionally encourage overconsumption unless complemented by behavioral nudges and communication strategies (Kirkman and Voulvoulis, 2017; Kollmuss and Agyeman, 2002).

Thus, in this study, the impact of door-to-door selective waste collection systems on household waste generation under conditions of external pressure is assessed. The COVID-19 pandemic is employed as an exogenous shock to isolate the behavioral effects associated with infrastructure-enabled convenience, rather than to evaluate the pandemic’s direct consequences. This analytical lens facilitates the examination of the dynamic interplay between individual decision-making and environmental incentives within the context of contemporary waste management (Buheji, 2020; Thøgersen, 2014).

3.1.1 Theoretical background

The conceptual framework of this study is grounded in three interrelated theoretical domains: behavioral economics, the Perceived Disposal Ease Bias, and the circular economy rebound effect. Together, these perspectives provide a lens through which the unintended behavioral consequences of selective waste collection infrastructure can be analyzed, particularly under conditions of external shocks. First, behavioral economics offers a critical departure from the classical assumption of fully rational actors in environmental decision-making. Instead of treating individuals as utility-maximizing agents with complete information, behavioral approaches emphasize cognitive biases, heuristics, and context-specific motivators (Kollmuss and Agyeman, 2002; Thøgersen, 2014). In the realm of municipal waste management, decisions related to sorting, recycling, and disposal are often shaped by perceived effort, habits, and moral licensing, rather than by a consistent commitment to environmental values (Derksen and Gartrell, 1993; Schultz et al., 1995). The literature has increasingly recognized that infrastructural design, especially the ease and immediacy of waste disposal, can systematically alter household behavior, sometimes undermining broader sustainability objectives (Barr et al., 2003).

Second, the study draws on the concept of the Perceived Disposal Ease Bias, a form of behavioral distortion wherein individuals misinterpret infrastructural convenience as an environmental virtue. As described by (Chen,

2021), it could emerge when improved access to recycling or disposal systems reduces the perceived environmental cost of consumption, leading to elevated material throughput. Even in the absence of significant changes in ecological awareness, convenience can trigger behavior that is environmentally counter-productive. When waste sorting becomes effortless due to infrastructure, such as curbside bins or door-to-door collection, consumers may feel less compelled to reduce consumption or reuse materials (Zink and Geyer, 2017; Ganguly and Chakraborty, 2021).

Third, the analysis is grounded on the circular economy rebound effect, which refers to the paradoxical outcome wherein efficiency gains in resource use or waste processing incentivize greater consumption overall (Figge and Thorpe, 2019; Metić and Pigosso, 2022; Zink and Geyer, 2017). While the circular economy aims to minimize waste through reuse, recycling, and regeneration, its implementation can unintentionally lower the psychological and financial costs of waste generation. In this context, improvements in collection systems may not lead to lower net waste production but instead create a false sense of environmental responsibility that facilitates increased disposal (Guzzo et al., 2024; Lowe et al., 2024). This effect is particularly relevant when evaluating the success of selective collection infrastructure, which may boost recycling rates but also reinforce unsustainable consumption patterns. By integrating these three theoretical strands, the present study seeks to assess whether door-to-door selective collection systems, when introduced under exogenous pressure, serve as facilitators of environmentally beneficial behavior or, conversely, trigger rebound dynamics rooted in convenience-driven biases.

3.1.2 Inconsistent mechanisms behind waste generation

The identification of the determinants of waste generation has been recognized as a complex and multifaceted challenge. A wide range of studies has emphasized the considerable influence of socio-economic, demographic, and cultural variables on waste generation patterns (Amaya et al., 2019; Saphores et al., 2006; Van Fan et al., 2025). Demographic characteristics, geographic contexts, income levels, educational attainment, household size, and degrees of urbanization have consistently been identified as key factors shaping waste

generation rates and disposal behavior. Nonetheless, the empirical findings remain often contradictory across different contexts.

Socio-demographic variables such as gender, age, education, and income have been highlighted as significant predictors of recycling behavior (Saphores et al., 2006). It has been observed that older individuals were more likely to engage in recycling programs, for example, in both US (Jakus et al., 1997) and Japan (Matsumoto, 2011), although other studies failed to find any statistically significant relationship between age and recycling behavior (Werner and Makela, 1998). Gender has also been found to play a pivotal role in household waste management decisions, though the strength and direction of its influence have been shown to vary across different cultural and socio-economic environments. While higher rates of waste separation among women have been shown (Ekere et al., 2009) and reinforced by studies reporting greater recycling participation among women (Schultz et al., 1995; Sidique et al., 2010), other investigations have reported no significant gender-based differences (Gamba and Oskamp, 1994; Vining and Ebreo, 1990).

Income has been identified as another critical factor, with higher income levels generally associated with greater participation in recycling activities (Gamba and Oskamp, 1994). However, other studies have indicated that increased income may also correspond with higher overall waste generation (Amaya et al., 2019; Khan et al., 2016). It has further been noted that cultural norms and incentive structures may moderate this relationship, as demonstrated in findings where higher income did not necessarily lead to increased waste generation (Zorpas et al., 2017). The relationship between education and recycling behavior has similarly been subject to divergent interpretations. A positive association between higher educational attainment and selective waste disposal behavior has been reported (Derksen and Gartrell, 1993; Jakus et al., 1997; Kala et al., 2020). Nevertheless, the efficacy of education as a driver of sustainable waste practices has been shown to be contingent upon contextual factors such as infrastructure availability and community engagement. As a result, discrepancies in recycling behavior have been observed even among equally educated populations (Bandara et al., 2007).

Although it has been demonstrated that larger households tend to generate greater absolute volumes of waste (Rybova, 2019; Rybová et al., 2018), the influence of household size on waste management practices remains inconclusive. In certain cases, larger household units have adopted more efficient waste man-

agement strategies, resulting in reduced per capita waste generation (Van Fan et al., 2025). Cultural norms and socio-economic factors have likewise been shown to exert highly variable effects on waste management behaviors. In developing countries, for instance, significant barriers to effective waste handling have been attributed to infrastructural deficiencies and economic inequality (Jagun et al., 2023). In contrast, it has been found that economic downturns in European contexts often correlate with a reduction in waste generation, indicating a context-dependent relationship between economic conditions and waste production (Namlis and Komilis, 2019). Although general patterns can be observed in the influence of socio-economic, demographic, and cultural factors on waste generation and management, the findings across the literature remain inconsistent. These discrepancies highlight the complex and localized nature of the determinants involved. Accordingly, a need has been identified for waste management strategies that are not only flexible and context-sensitive but also capable of adapting to evolving socio-economic dynamics and behavioral patterns.

3.1.3 Waste management systems and consumer behavior

The evolution of waste management systems over recent decades has been marked by significant transformations in environmental sustainability practices and strategies. Contemporary systems, including collection islands, door-to-door selective waste collection schemes, and municipal waste reduction initiatives, have been implemented with the objective of minimizing adverse environmental impacts and enhancing recycling performance. The global proliferation of modernized waste management structures and the widespread adoption of selective collection systems have been increasingly documented (Luhar et al., 2022; Sharma et al., 2020; Patrício Silva et al., 2021). These infrastructural advancements have been associated with increased environmental awareness and observable improvements in public behavior regarding waste disposal (Benson et al., 2021). Such developments have been attributed, in part, to the role of convenience as a key determinant in littering and waste separation habits. The practice of separating waste at the household level has been perceived as

time-intensive and space-demanding, thereby acting as a deterrent to active participation in selective waste practices.

Empirical support for this interpretation has been provided by (Vassanadumrongdee and Kittipongvises, 2018), whose study in Bangkok revealed that the primary obstacles to participation in selective waste collection were identified as the lack of suitable containers (21.9%), insufficient drop-off points (20.4%), and the perceived time burden of sorting waste (19.5%). Accordingly, convenience has been repeatedly identified in the literature as a critical factor influencing household engagement in waste management (Ando and Gosselin, 2005; Owusu et al., 2013; Sidique et al., 2010; Timlett and Williams, 2008). It has been emphasized that the availability and accessibility of supporting infrastructure are essential to encourage participation (Bernstad et al., 2013). Furthermore, not only the presence of waste collection facilities, but also their spatial proximity and placement can significantly influence recycling behavior (Boldero, 1995; Domina and Koch, 2002; González-Torre and Adenso-Díaz, 2005; Hage et al., 2009; Lange et al., 2014).

In a study conducted in Vietnam (Nguyen et al., 2015), the introduction of selective waste bins in Hanoi resulted in a substantial increase in the proportion of compostable waste collected, rising from 7 percent to 30 percent. Similarly, (Derksen and Gartrell, 1993) found that even individuals with low levels of environmental awareness exhibited higher participation rates in recycling when convenient collection systems, such as curbside bins, were made available. Data from US households further confirmed that access to curbside recycling services had a positive influence on source separation behavior, although the magnitude of the effect was found to vary by waste type (Jenkins et al., 2003). Moreover, research by (Kollmuss and Agyeman, 2002) revealed that the quantity of separately collected waste could be tripled when drop-off points were located in close proximity to households, particularly in the absence of curbside options. These effects are especially pronounced in developing countries, where the absence of integrated waste management systems has been associated with increased waste generation and elevated levels of littering (Guerrero et al., 2013).

Empirical findings indicate that poor infrastructural conditions hinder the transition from waste disposal to resource recovery, thereby intensifying waste-related problems (Goulart Coelho et al., 2017; Henry et al., 2006; Narayana, 2009). These infrastructural deficiencies have been shown to impact not only

municipal solid waste but also construction and demolition waste management systems. The uncontrolled disposal of waste has been consistently linked to inadequate infrastructure (Maalouf et al., 2020; Nadeem et al., 2023; Parrot et al., 2009; Zabaleta and Rodic, 2015). In this regard, public engagement and the provision of information have been identified as essential components for enhancing the efficiency and effectiveness of waste management systems (Kirkman and Voulvoulis, 2017). The success of waste management initiatives depends not only on the adequacy of infrastructure but also on the level of public involvement and the transparency of communication strategies (Manowong and Ogunlana, 2008). Where communication and planning are poorly executed, public resistance is often encountered, which in turn poses significant obstacles to the development and implementation of waste management systems (Rootes, 2009).

The question of which types of infrastructure deployment prove most effective under varying circumstances remains underexplored in academic literature. A notable contribution in this area has been made by (Struk, 2017), whose study conducted in the Czech Republic demonstrated that both curbside collection and selective island systems significantly increased the proportion of waste that was properly separated. (Struk, 2017) proposed a typology of waste collection systems based on the degree of convenience offered to users. Three principal categories of infrastructure were identified:

1. **Selective yards:** These are designated, controlled-access facilities where only uncontaminated, pre-sorted waste is accepted. While a high quality of service is ensured, access to such facilities is often constrained due to high temporal and logistical costs. As a result, participation rates may be limited despite the potential for efficient material recovery.
2. **Selective islands:** These consist of publicly accessible collection containers for sorted waste, typically located in centralized or semi-centralized public areas. Compared to selective yards, these systems are more widespread and cost-effective. However, the requirement for individuals to transport waste outside the household still represents a barrier for some participants, thus moderating their convenience.
3. **Curbside collection:** This category represents the most convenient and economically accessible option. It generally includes two subtypes:

bins and bags. Bins, while more expensive to deploy, offer greater storage capacity and are often used for specific waste streams such as glass. Bags, on the other hand, are more cost-effective and user-friendly, but their limited capacity and incompatibility with certain waste types restrict their universal application.

The findings of (Struk, 2017) suggest that the effectiveness of waste collection infrastructure is closely tied to the balance between service accessibility, operational cost, and user convenience. However, further empirical research is needed to understand how these factors interact under different cultural, economic, and regulatory contexts. It was further observed in the study that municipalities lacking either form of collection infrastructure exhibited the lowest rates of source-separated waste, particularly with respect to recyclable materials such as paper and plastic. Moreover, curbside collection was confirmed to be the most effective method for increasing waste separation at the source, at least in quantitative terms. These findings align with prior empirical results (Abbott et al., 2011; Barr et al., 2003; Folz, 1991). Notably, (Abbott et al., 2011) identified curbside collection as a pivotal driver of improved recycling performance, while (Folz, 1991) demonstrated that participation rates were nearly doubled under curbside collection schemes compared to alternative systems.

Door-to-door selective waste collection systems have been shown to enhance user convenience by significantly reducing the time and physical effort required for sorting and transporting waste to external collection points (Wagner and Broaddus, 2016; Pérez et al., 2021). However, while such systems have produced measurable improvements in recycling rates, their implementation may also give rise to unintended behavioral consequences. Although COVID-19 and the related containment measures were applied in a largely uniform manner across all regions (Benson et al., 2021; Ganguly and Chakraborty, 2021; Patrício Silva et al., 2021), variation in behavioral outcomes has nonetheless been observed. This heterogeneity may be attributable to psychological and contextual factors, including the Perceived Disposal Ease Bias, whereby the ease of waste disposal is overestimated due to the presence of convenient infrastructure (Chen, 2021; Figge and Thorpe, 2019; Zink and Geyer, 2017). As a result, differential responses may arise depending on both the availability and the perceived accessibility of selective collection systems at the local level.

To accurately capture these heterogeneous behavioral effects, the use of a natural experiment design has been deemed particularly suitable. This methodological approach relies on exogenous shocks (e.g., the COVID-19 pandemic) that are unrelated to local policy decisions or infrastructural characteristics. Given that the implementation of COVID-related restrictions was exogenous to municipal waste management policies, it has provided a quasi-randomized setting in which the presence or absence of selective collection infrastructure can be exploited to isolate causal effects on household waste behavior. By circumventing the issue of self-selection and enhancing internal validity, this framework offers a robust empirical strategy for evaluating the behavioral consequences of environmental interventions.

3.2 Materials and methods

3.2.1 Data and research design

A range of selective waste collection methods has been implemented across municipalities in Hungary. Among these, the curbside double-bin system, where households are provided with two distinct containers, one for plastic and one for paper waste, represents one of the most commonly used approaches. In certain regions, a curbside bag system has also been adopted, whereby designated bags, rather than containers, are distributed to residents for the purpose of selective collection. Additionally, selective islands have been installed in some municipalities, particularly within smaller settlements, offering centralized locations for the deposit of recyclable materials.

The principal aim of this study is to evaluate the impact of introducing the bin-based collection system, commonly used across Europe, on the quantity and composition of municipal solid waste. The data employed in this analysis were obtained from the official repositories of the Hungarian Central Statistical Office (Hungarian Central Statistical Office, 2025b), which provide detailed annual waste collection records for a sample of 93 Hungarian municipalities. The dataset includes measurements for both selective and mixed waste streams, reported in kilograms per capita. Selective waste refers to the

volume of separately collected recyclable materials, while mixed waste denotes the amount of non-separated municipal waste generated.

Given the well-documented influence of income on waste generation (Khan et al., 2016), income was considered as a control variable. However, as individual-level per capita income data were not available, municipal-level taxable income was utilized as a proxy indicator for financial well-being. This substitution enables the assessment of potential relationships between income levels and patterns of waste generation and separation. To account for the potential influence of the COVID-19 pandemic on waste-related behavior and infrastructure use, the dataset spans the period from 2012 to 2023. Descriptive statistics for the variables included in the analysis are presented in Table 3.1.

Table 3.1: Descriptive statistics of the variables

Variable	Obs.	Mean	Std. dev.
Population	1,116	43,740.54	175,569.9
Taxable income (1000 HUF/capita/year)	1,116	1,046.61	587.30
Mixed waste (kg/capita/year)	1,116	206.40	84.27
Selective waste (kg/capita/year)	1,116	30.69	33.05

Based on 1,116 observations, substantial heterogeneity has been identified within the population of the municipalities included in the dataset. This variation is attributable to the inclusion of both small rural settlements and large urban centers, including Budapest. The smallest municipality within the sample reported a population of only 144 inhabitants, whereas Budapest, the largest city represented, had a population exceeding 1.7 million. In terms of annual personal taxable income per capita, the average was approximately 1.046 million HUF, with a standard deviation of 587.30 thousand HUF. These statistics indicate pronounced income disparities across municipalities. The minimum observed value was 151 thousand HUF, while the maximum reached 3.35 million HUF per capita annually, highlighting considerable economic heterogeneity that may affect local consumption behavior and patterns of waste generation.

The average annual per capita generation of mixed waste was measured at 206.40 kilograms, with a standard deviation of 84.27 kilograms. This wide

variation likely reflects differences in urbanization, household consumption, and the availability and quality of local waste management infrastructure. In contrast, the mean annual per capita volume of selectively collected waste was significantly lower, recorded at 30.69 kilograms. The latter figure indicates that some municipalities lacked selective waste collection systems during at least part of the analyzed period (2012–2023). This variability is likely associated with differences in infrastructural development, public participation, and institutional support for selective waste management.

The heterogeneity observed in the sample can be attributed to the non-uniform implementation of selective waste collection systems across Hungarian municipalities. Although the Waste Framework Directive (European Parliament and Council, 2008) mandated the establishment of separate collection schemes throughout the European Union, full compliance was required of Member States only by January 1, 2015. As a result, during the period between 2012 and 2015, many smaller municipalities in Hungary had not yet implemented any form of selective waste collection. In addition, the lack of a centralized, publicly accessible database systematically documenting the type and timing of selective waste collection systems, such as curbside double-bin, curbside selective bag, and selective island schemes, has indicated a challenge to comprehensive data acquisition. As a result, inclusion in the sample was limited to those municipalities for which sufficient information was available either through public data sources or direct consultations with local authorities. This approach allowed for the precise identification of whether the curbside double-bin system had been introduced prior to the onset of the COVID-19 pandemic in 2020. Based on this classification, the municipalities were divided into two groups: treatment and control. A total of 23 municipalities in which the bin system had already been implemented were assigned to the treatment group, while 70 municipalities without such a system were assigned to the control group. A summary of the group composition is presented in Table 3.2.

Table 3.2: Descriptive statistics of municipalities

Settlement type (population size)	Count	Percentage
Small settlement (< 10,000)	45	48.39%
Medium-sized town (10,001–50,000)	32	34.41%
Large town (50,001–100,000)	7	7.53%
County seats and major cities (> 100,000)	8	8.60%
Capital: Budapest (Special case) (> 100,000)	1	1.08%
Total	93	100.00%

Most municipalities included in the sample were classified as small settlements with populations of up to 10,000 inhabitants, or as medium-sized towns with populations ranging between 10,001 and 50,000 inhabitants. In these locations, the curbside double-bin selective waste collection system was generally not implemented. Larger towns, defined as those with populations between 50,001 and 100,000 inhabitants, accounted for 7.53% of the total sample. County seats and major cities with populations exceeding 100,000 inhabitants represented 8.60% of the sample. Budapest, as the capital city and a unique administrative entity, was treated as a special case within the dataset due to its distinct demographic and infrastructural characteristics.

3.2.2 Methodology

In this study, a structured econometric framework is employed to evaluate the extent to which the presence of curbside double-bin selective waste collection systems influenced municipal waste generation. A single model specification is utilized to identify the effect of infrastructure on waste-related behavioral outcomes under exogenous pressure. The classical difference-in-differences (DiD) methodology is applied, which is traditionally formulated in a two-period context involving a clearly defined pre-treatment and post-treatment phase, as well as delineated treatment and control groups. The causal effect is estimated by measuring the differential change in the outcome variable over time between treated and untreated observational units. The

standard DiD estimator, as formalized by Goodman-Bacon (2021), is expressed as Equation 3.1:

$$\hat{\delta}_{DiD} = (\bar{Y}_{T,post} - \bar{Y}_{T,pre}) - (\bar{Y}_{C,post} - \bar{Y}_{C,pre}) \quad (3.1)$$

where $\bar{Y}_{T,post}$ and $\bar{Y}_{T,pre}$ denote the average outcomes for the treated group after and before the intervention, respectively, while $\bar{Y}_{C,post}$ and $\bar{Y}_{C,pre}$ represent the corresponding averages for the control group. This analytical setup is based on the parallel trends assumption, which posits that, in the absence of treatment, the outcome trajectories of both groups would have evolved in a similar manner over time. In the context of the present analysis, however, the treatment, defined as the availability of selective waste collection bins during an exogenous shock (i.e., the COVID-19 pandemic), was not introduced at a uniform point in time. Instead, the dataset spans multiple years and includes municipalities that vary in both the timing and status of treatment exposure. To account for this variation across time and space, a two-way fixed effects (TWFE) regression model is employed. This model serves as a generalized extension of the classical difference-in-differences approach, allowing for multiple periods and controlling for unobserved, time-invariant heterogeneity across municipalities as well as common temporal shocks that may influence waste generation patterns (Callaway and Sant'Anna, 2021; Imai and Kim, 2021). The estimated model can be written as follows (Equation 3.2):

$$Y_{it} = \alpha + \beta_1(Bin_i \times COVID_t) + \beta_2Income_{it} + \gamma_t + \mu_i + u_{it} \quad (3.2)$$

In this specification, Y_{it} represents the amount of waste collected in municipality i during year t , expressed in kilograms per capita. The dependent variable may refer to either selectively or non-selectively collected waste. Bin_i is a binary indicator variable equal to 1 if the double-bin selective waste collection system was implemented in municipality i , and 0 otherwise. $COVID_t$ is a dummy variable taking the value of 1 for observations during the COVID-19 period and 0 otherwise. The interaction term $Bin_i \times COVID_t$ represents the primary variable of interest, capturing the differential impact of the selective bin system during the pandemic era. Municipality-level fixed effects μ_i are included to control for time-invariant characteristics specific to each municipality, while year fixed effects γ_t account for temporal shocks that are common across all municipalities. The variable $Income_{it}$ denotes annual per capita

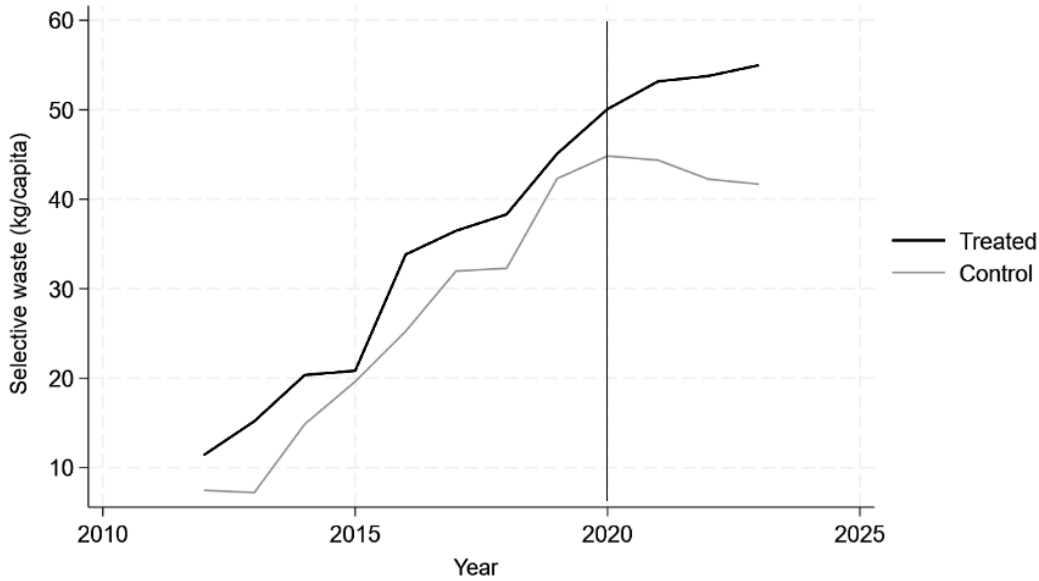
taxable income (expressed in thousand HUF) and is included as a control to account for economic differences across municipalities and over time. The term u_{it} represents the idiosyncratic error component.

The identification of the causal effect in this specification relies on the parallel trends assumption, which holds that in the absence of treatment, municipalities with and without the selective bin system would have exhibited similar trends in waste generation. Although differences may exist in baseline levels of waste generation or in responsiveness to external shocks, the inclusion of municipality and year fixed effects is intended to mitigate the influence of such time-invariant and period-specific confounding factors. Under this identifying assumption, the coefficient β_1 can be interpreted as the average treatment effect of the selective bin system during the pandemic period.

The validity of the DiD approach hinges critically on the assumption that, in the absence of treatment, the treated and control groups would have exhibited parallel trends in the outcome variable over time. This condition, known as the *parallel trends assumption*, constitutes a central identification requirement for causal inference in DiD models. In support of this assumption, Figure 3.1 presents the evolution of selectively collected waste in treated and control municipalities during the pre-treatment period. Although baseline levels of waste generation differ between the two groups, their trajectories between 2013 and 2019 reveal similar patterns of increase. This visual evidence suggests that the groups followed approximately parallel trends prior to the intervention, thereby reinforcing the plausibility of the parallel trends assumption and enhancing the internal validity of the causal estimates obtained from the DiD specification.

Furthermore, the adoption of a natural experiment framework strengthens the credibility of the analysis by exploiting an exogenous shock, namely, the COVID-19 pandemic, that is plausibly uncorrelated with municipal-level waste management policies. Given that the pandemic-related restrictions were imposed externally and simultaneously across all municipalities, the intervention can be interpreted as quasi-random. This exogeneity reduces the likelihood of confounding by unobserved factors and provides a more credible setting for identifying the behavioral impact of selective bin systems on household waste generation.

Figure 3.1: Parallel trends assumption



3.3 Results and discussion

The empirical analysis is conducted using a single TWFE regression model to estimate the impact of door-to-door selective waste collection systems during an exogenous shock. The treatment effect is identified through the interaction of two binary indicators: one denoting the presence of curbside selective waste collection infrastructure, and the other indicating whether the observation period falls within the timeframe of the pandemic. This model specification facilitates the estimation of differential changes in waste generation attributable to the implementation of selective bin systems under conditions of external pressure. To control economic heterogeneity across municipalities, annual per capita taxable income is included as a covariate in the regression model. To account for potential autocorrelation within municipalities over time, standard errors are clustered at the municipal level, ensuring that inference is robust to within-group correlation in the error terms.

The results of the regression analysis are presented in Table 3.3, showing the estimated effects of the interaction between the presence of door-to-door selective waste collection infrastructure and the COVID-19 period on munic-

ipal waste generation. The coefficient on the interaction term is found to be positive and statistically significant in the case of selectively collected waste. This result indicates that municipalities equipped with curbside bin systems generated, on average, 11.76 kilograms more selectively collected waste per capita per year during the pandemic period, relative to municipalities lacking such infrastructure. In contrast, the coefficient for mixed waste is estimated to be negative but statistically insignificant, suggesting that the presence of selective bins did not lead to a meaningful change in the quantity of residual (non-separated) waste collected during the shock period. The control variable representing annual per capita income is not found to be significantly associated with either waste category. This suggests that income variation across municipalities does not account for the observed treatment effects, thereby reinforcing the interpretation that the changes in waste generation are attributable to the selective bin infrastructure under external pressure.

Table 3.3: TWFE regression results for selective and mixed waste

Variables	Selective waste	Mixed waste
Interaction DiD Effect	11.76** (5.32)	-8.64 (7.15)
Personal Income (1000 HUF)	-0.0057 (0.0058)	0.0068 (0.013)
Constant	36.74*** (7.06)	198.75*** (15.6)
N	1,116	1,116
R ²	0.401	0.035

Notes: Robust standard errors in parentheses. Waste quantities are reported in kilograms per person per year (kg/person/year).

To further assess the credibility of identifying assumptions underlying the regression model, a placebo test is performed by introducing a false treatment period that precedes the actual exogenous shock. Specifically, an interaction term is constructed between the treatment group indicator and a pre-treatment period spanning the years 2016 to 2018. This placebo specification is then

estimated using the same TWFE regression framework applied in the main analysis. The rationale for this approach is grounded in the parallel trends assumption: if this assumption holds, no significant differences should be observed between treated and control municipalities during the placebo period, as the treatment (i.e., selective bin infrastructure under COVID-related pressure) had not yet occurred. The results of the placebo regression, summarized in Table 3.4, lend support to the validity of the parallel trends assumption.

Table 3.4: Placebo TWFE regression results for selective and mixed waste

Variables		Selective waste (placebo)	Mixed waste (placebo)
Interaction	Placebo	1.18	-0.71
Effect		(2.91)	(6.04)
Personal	Income	-0.0012	0.0035
(1000 HUF)		(0.0057)	(0.0123)
Constant		32.07	202.17
		(7.01)	(15.17)
N		1,116	1,116
R ²		0.717	0.844

Notes: Robust standard errors in parentheses. Waste quantities are reported in kilograms per person per year (kg/person/year). The placebo regression includes municipality and year fixed effects, clustered at the city level.

The estimated coefficient on the placebo interaction term is found to be small in magnitude and statistically insignificant for both selectively and non-selectively collected waste. In both cases, the 95% confidence intervals include zero, indicating that no differential trends existed between treated and control groups during the pre-treatment period. These findings suggest that the observed effects in the main specification are unlikely to be driven by pre-existing differences in waste generation trends, thereby reinforcing the internal validity and credibility of the causal interpretation.

To further evaluate the robustness of the estimated treatment effects, a leave-one-out sensitivity analysis was conducted. In this procedure, the six largest municipalities (Budapest, Debrecen, Miskolc, Pécs, Szeged, and Győr) were sequentially excluded from the sample, and the TWFE model was re-

estimated for each restricted specification. These municipalities were selected due to their status as major urban centers, which may exert disproportionate influence on the estimates owing to their population size or distinctive waste management infrastructures. As reported in Table 3.5, the estimated coefficients on the interaction term for selectively collected waste remain positive and statistically significant across all model variants.

Table 3.5: Leave-one-out robustness check (Interaction effects only)

City Excluded	Selective Waste	Mixed Waste
Budapest	12.13** (5.44)	-8.30 (7.28)
Pécs	12.45** (5.45)	-6.89 (7.18)
Debrecen	12.22** (5.46)	-8.41 (7.35)
Miskolc	11.71** (5.50)	-8.75 (7.38)
Szeged	11.81** (5.48)	-8.75 (7.35)
Győr	12.15** (5.45)	-9.66 (7.25)
R²	0.7209 – 0.7224	0.8443 – 0.8456
N	1,104	

Note: Robust standard errors in parentheses.

The estimated treatment effects range narrowly between 11.71 and 12.45 kilograms per capita per year, indicating strong consistency. Conversely, the estimated coefficients for mixed waste remain negative but statistically insignificant throughout all iterations of the analysis. These results suggest that the main findings are not being driven by outlier municipalities. Rather, the positive and significant treatment effect associated with the presence of selective bin infrastructure appears to be stable across varying sample compositions.

The robustness of the estimates enhances the internal validity of the empirical strategy and reinforces the causal interpretation of the behavioral effects identified in the analysis.

3.4 Discussion

Overall, the findings provide empirical support for the conclusion that door-to-door selective waste collection systems induced a measurable behavioral response under conditions of external pressure. This response is reflected in a significant increase in the volume of selectively collected waste, without a corresponding decrease in mixed (non-selective) waste. Such a pattern is consistent with the presence of a perceived disposal ease bias, whereby improvements in convenience result in higher overall waste generation rather than substitution between waste streams. These results may be interpreted not solely as a shift in sorting behavior, but as a broader change in household disposal habits, driven by the perceived convenience of disposal infrastructure. The increase in selective waste is thus indicative of a structural behavioral shift rather than merely improved compliance.

Multiple studies have documented the complex impacts of the COVID-19 pandemic on municipal waste generation patterns. In many regions, overall municipal waste volumes were observed to decline because of reduced economic activity (Sarmiento et al., 2022). In parallel, a significant increase in selective waste, particularly packaging materials and single-use plastics, was reported, largely attributed to the rise in online shopping and home deliveries (Guzzo et al., 2024; Nguyen et al., 2015). Additionally, the widespread use of personal protective equipment, such as face masks and gloves, introduced new waste streams into the municipal system (Patrício Silva et al., 2021). Although shifts in consumer behavior during the pandemic (Benson et al., 2021; Ganguly and Chakraborty, 2021; Patrício Silva et al., 2021) and the circular economy rebound effect (Chen, 2021; Figge and Thorpe, 2019; Zink and Geyer, 2017) have been examined independently in prior literature, the interaction between crisis-induced constraints and behavioral distortions linked to waste infrastructure remains underexplored. The current study addresses this intersection and gap by providing quasi-experimental evidence on the causal effects of infrastructure-enabled convenience.

Regression results indicate that municipalities equipped with door-to-door selective bin systems generated, on average, 11.76 kilograms more selectively collected waste per capita annually, relative to municipalities lacking such infrastructure. This effect is statistically significant and suggests that convenience-based infrastructure may reinforce existing consumption behaviors when external constraints are present (Chen, 2021; Guzzo et al., 2024). In contrast, no significant change was detected in the quantity of mixed waste, implying that the observed increase in selective waste was not due to substitution across waste streams, but rather reflected additional overall waste generation. This pattern aligns with the circular economy rebound effect, as described by Zink and Geyer (2017) and Figge and Thorpe (2019), in which improved waste infrastructure can lower the perceived cost of consumption, indirectly incentivizing greater resource use. Notably, our findings expand this model by demonstrating that behavioral rebound can be triggered not only by efficiency gains, but also by psychological mechanisms such as the Perceived Disposal Ease Bias (Chen, 2021).

As earlier studies suggest, when waste separation becomes effortless, individuals may develop a false sense of environmental responsibility, leading to behaviour that ultimately undermines sustainability (Kollmuss and Agyeman, 2002; Lowe et al., 2024; Patrício Silva et al., 2021). This study is among the first to empirically confirm this behavioral distortion under quasi-experimental conditions. The COVID-19 period thus created an environment in which infrastructural variables could be separated from voluntary behavioral shifts, allowing for causal identification of disposal-related decision-making (Guzzo et al., 2024). In line with previous empirical evidence, the results further suggest that municipal income levels did not significantly predict differences in waste generation patterns (Abbott et al., 2011; Barr et al., 2003). This may reflect either the relatively limited heterogeneity in income across the sample or the dominant role of infrastructure and contextual factors in shaping household waste behaviors. Moreover, while our results are consistent with findings from higher-income contexts (Jenkins et al., 2003), they diverge from patterns observed in developing countries, where the presence of infrastructure alone is often insufficient to drive behavior due to socio-institutional constraints (Guerrero et al., 2013). This suggests that convenience-based effects emerge only once infrastructural barriers are minimized.

Overall, the results underscore the importance of examining the ways in which environmental infrastructure interacts with behavioral incentives under real-world conditions. While selective waste collection systems are typically designed to enhance recycling performance, it must be recognized that such systems may inadvertently contribute to increased total waste generation if convenience-driven behavioral biases are not adequately addressed. If these biases remain unmanaged, they may offset the very environmental gains that selective collection systems aim to achieve. Therefore, a careful balance must be struck between infrastructure expansion and behavioral regulation. Accordingly, it is suggested that the implementation of selective waste collection infrastructure be accompanied by complementary policy interventions and targeted public awareness campaigns. Such measures are essential to ensure that the behavioral responses elicited by convenience-enhancing systems align with broader sustainability objectives.

3.5 Conclusions

This study has provided novel empirical evidence on the behavioral impact of door-to-door selective waste collection systems under conditions of external disruption. By leveraging the COVID-19 pandemic as an exogenous shock, a quasi-experimental framework was applied to isolate the effect of infrastructure-enabled convenience on household waste generation. It has been demonstrated that the introduction of curbside bin systems was associated with a statistically significant increase in selectively collected waste, while no corresponding reduction was observed in mixed waste. This finding suggests that convenience-enhancing infrastructure may lead not only to improved sorting, but also to an overall rise in waste generation. The results contribute to the broader literature on the circular economy rebound effect by offering causal support for the Perceived Disposal Ease Bias hypothesis. Infrastructure that simplifies disposal processes may unintentionally encourage overconsumption and reduce perceived environmental costs. As such, selective waste collection systems, although successful in raising recycling participation, may generate counterproductive behavioral responses if implemented in isolation. To conclude, a significant gap in literature has been addressed by

analyzing the behavioral implications of infrastructure-driven convenience in the context of an exogenous shock.

Nevertheless, several limitations must be acknowledged. First, the classification of municipalities was based on the confirmed presence of door-to-door bin systems during the pandemic period, without access to precise information regarding the exact timing of system implementation. This limitation constrains the ability to evaluate dynamic treatment effects and may affect the generalizability of the results. Second, the dataset does not contain detailed information on waste composition, restricting the analysis of substitution patterns between recyclable and non-recyclable waste streams. Third, qualitative dimensions of waste management, such as contamination rates in selectively collected waste, are not accounted for. Fourth, qualitative aspects of citizen engagement and sorting quality could not be incorporated. These factors may substantially influence the true environmental effectiveness of selective collection systems and are therefore relevant for a more nuanced evaluation.

Further research is warranted to disentangle the mechanisms underlying the circular economy rebound effect, and to explore how recycling-oriented infrastructure may alter household disposal behavior beyond mere sorting. A more comprehensive understanding of these behavioral dynamics could inform the design of complementary policy instruments aimed at mitigating overall waste generation while preserving the environmental benefits associated with higher recycling rates.

Chapter 4

Is It Greener on the Right Side? The Relationship Between Political Preferences and Environmental Behavior from Hungary

4.1 Introduction²

Environmental issues are at the forefront of public discourse throughout the world, especially in developed countries. Climate change and other environmental problems often dominate discussions in international organizations, but there is also increasing demand for “sustainable living” at the individual level. As other countries and organizations, the European Union has set out a list of ambitious environmental goals. The EU’s goal is to become fully climate neutral, that is, to ensure that its economic activities do not generate greenhouse gas emissions, by 2050. This is part of the European Green Deal, whose objectives include decarbonizing the energy sector, making buildings more sustainable and energy efficient, introducing cleaner, cheaper, and healthier forms of transport, “greening” agriculture and industrial production, and increasing the share of recycled materials.

Achieving such goals, however, may be difficult. Pro-environmental behavior can be regarded as a luxury good. There are therefore differences across income groups in attitudes toward environmental issues (Barnett and Morse,

²This chapter is based on a co-authored article with Barna Bakó, Zombor Berezvai, and Péter Isztin, published in *East European Politics & Societies and Cultures* in 2025 (DOI: <https://doi.org/10.1177/08883254251333781>).

1963; Hirsch, 1976; Inglehart, 1971; Bishop et al., 1976; Pearce and Atkinson, 1993; Gamba and Oskamp, 1994). That is because the poor have much more pressing concerns than worrying about sustainability, a phenomenon scholars often refer to as “too poor to be green” (Martinez-Alier, 1995; Van Kempen et al., 2009). As income increases, quality of life considerations come to the fore, and the relative value of clean water, air and natural treasures (parks, canyons, coral reefs, wildlife, etc.) increases. Higher income also creates the opportunity to offset and correct the negative environmental impacts of production.

Attitudes and behavior toward the environment are often divided across political lines. Typically, left-wing individuals and parties are thought to favor environmental protection more and to engage in a greater level of (allegedly) environmentally friendly practices. Much of the empirical literature corroborates this view (Dunlap et al., 2001; Feygina et al., 2009; McCright and Dunlap, 2011), with one notable exception. McCright et al. (2015) find that the left-right division on environmentalism applies to a lesser degree in Central and Eastern Europe, where right-leaning individuals have a more favorable attitude to environmentalism, as evidenced by a greater willingness to pay to fight climate change. This evidence is based on survey data.

The present article, in contrast, contributes to the literature by examining revealed preferences, through observation of actual behavior. In particular, we connect the vote shares of left- and right-wing politicians in Budapest districts with a particular environmentally friendly practice: waste separation. Waste separation is the most common action at the household level that Europeans undertake to address climate change, according to the Eurobarometer surveys. Furthermore, waste generation habits strongly indicate environmental attitudes. The literature suggests that the amount of waste collected separately is a good measure of pro-environmental attitudes (Aphale et al., 2015; Grazhdani, 2016). Consistent with the findings of McCright et al. (2015) and contrary to widespread beliefs, we do not find a positive link between left-wing politics and pro-environmental behavior. In fact, we find just the opposite.

In the following, we first review the relevant literature. Next we present our methodology and data. Then we present our results, and discuss the findings. Finally, in the last section, we draw some conclusions.

4.2 The connection between political attitudes and environmental behavior

A great number of studies have attempted to identify the sociocultural and demographic drivers of waste generation (Lebersorger and Beigl, 2011; Parizeau et al., 2015; Talalaj and Walery, 2015; Ghinea et al., 2016), and many studies have examined factors influencing the success of waste separation programs (Ibáñez et al., 2011; Best and Kneip, 2011; Owusu et al., 2013; Bernstad et al., 2013; Mbiba, 2014; Xiao et al., 2017; Oyekale, 2018; Manomaivibool et al., 2018). Moreover, a few studies have analyzed the interaction between the two Aphale et al. (2015); Grazhdani (2016).

Several studies have aimed at identifying the drivers of waste generation. According to Saphores et al. (2006), the most commonly studied socio-demographic variables that play a role in waste generation are gender, age, education, and income. However, apart from the latter, there is no consensus on the effects of these variables. Numerous studies have come to completely opposite conclusions regarding the relationship between waste generation and age, gender, or education (Vining and Ebreo, 1990; Schultz et al., 1995; Jakus et al., 1997; Werner and Makela, 1998; Meneses and Palacio, 2005; Ekere et al., 2009; Sidique et al., 2010; Matsumoto, 2011). It appears that in the case of waste generation one of the most important and repeatedly identified drivers is the income level (Johnstone and Labonne, 2004; Talalaj and Walery, 2015; Gui et al., 2019; Romano et al., 2019).

The phenomenon of “too poor to be green” provides a good starting point for analyzing pro-environmental behavior. Direct and indirect evidence for it can be found in several studies on waste separation and waste management. Results indicate that households with considerable extra space (larger dwellings, backyards, gardens) are more willing to collect waste separately even without additional rewards (Lardinois and Furedy, 1999; Bennagen et al., 2002; Owusu et al., 2013). These households tend to be wealthier and more affluent (Owusu et al., 2013). It seems logical to assume that environmental awareness becomes a concern for people only beyond a certain income level, and that this level has a sociocultural aspect (Salkie et al., 2001; Johnstone and Labonne, 2004; van Beukering et al., 2009; Pampel, 2013). It is, however, important to emphasize again that high-income is not necessarily associated with a lower

environmental footprint; therefore, the relationship between income and environmentalism is ambiguous (Pampel, 2013).

In addition, several studies have demonstrated the relevance of political attitudes for pro-environmental behavior. The majority of these studies investigated Western European or North American countries. In a comprehensive study, Sánchez et al. (2015) investigated the attitudinal, sociodemographic, and political factors that affect the environmental practices of Spanish households. The authors analyzed the relationship between age, gender, education and political affiliation, on the one hand, and environmentally conscious behavior, such as waste separation, water saving, and the purchase of environmentally friendly products, on the other hand. The authors found that left-wing attitudes have a positive influence on both environmentally conscious consumption and environmentally conscious purchasing behavior. This is in line with other results, such as those by Witzke and Urfei (2001) for Germany, and Torgler and García-Valiñas (2007) and Vera-Toscano et al. (2008), both for Spain, who also concluded that people with a left-wing or liberal orientation are more sensitive to environmental issues. Using data from Italian voters, Caprara et al. (2006) argued that conservatives place more importance on stability and maintaining the status quo, while people with more liberal ideologies place more importance on civil rights and social issues.

North American and Australian studies show similar findings. Gromet et al. (2013) investigated the impact of political preferences on attitudes toward energy efficiency and energy-saving behavior. They conducted two studies in the United States. In the first study, the authors examined whether attitudes toward energy efficiency are polarized along political ideology. They demonstrated that people with a more conservative or right-wing political ideology were less supportive of the development of more energy-efficient technologies. In the second study, they examined in a real-choice context how this polarization influences demand for energy-efficient products. They showed that conservative individuals were willing to buy energy-efficient products (in this case, a more expensive light bulb) on financial grounds but when energy efficiency was framed in a pro-environmental context (as indicated by a label), their willingness to buy was significantly reduced. In other words, more conservative consumers were less likely to buy the same energy-efficient light bulb at the same price if it had a label saying that the light bulb is environmentally friendly. Similar results were found for the US and Canada by Hu et al. (2017)

and Fobissie (2019). This suggests that the shift to sustainability is more unpopular among conservatives (Costa and Kahn, 2013; Unsworth and Fielding, 2014) because it threatens the functioning of the current system (Jost et al., 2003; Antonio and Brulle, 2011). In turn, Morrison and Miller (2008) suggested that liberals and left-leaning individuals in the US prioritize issues related to the environment and sustainability, whereas Janoff-Bulman et al. (2009) and Kellstedt et al. (2008) claimed that such individuals also place greater importance on solving environmental problems that will seriously affect future generations.

Political attitudes were also found to be important in a comprehensive European study. McCright et al. (2015) analyzed survey data from 14 Western European and 11 former communist Central and Eastern European countries and concluded that there is much greater support for fighting climate change among individuals with left-wing ideologies in Western Europe. However, the same is not true for post-communists in Central and Eastern Europe, where right-wing individuals reported a high willingness to pay to combat climate change. One reason for this, the authors speculated, is that the definitions of political left and right in post-communist countries differ in the two halves of Europe, and that climate change is not a pivotal issue in the former Eastern bloc.

Sustainability and the fight against climate change are important to Hungarian voters, according to the Eurobarometer. According to the Manifesto Project data, right-wing parties in Hungary do not address this issue, while left-wing parties show only limited interest in environmental protection (Lehmann et al., 2023). It is therefore worth re-examining the relevance of political ideology for environmental attitudes in Central and Eastern Europe, and in Hungary in particular.

4.3 Data and methodology

We examine the relationship between political preferences and sustainability-related behavior. To operationalize these concepts, one could conduct a survey and employ regression analysis as an analytical tool (Caprara et al., 2006; Hu et al., 2017). However, surveys connected to political preferences are often not sufficiently accurate, most likely due to nonresponse bias and reporting

of false preferences (Shaiko et al., 1991; Enns et al., 2017). Similar problems might arise with sustainability-related questions where social desirability bias may be present (King and Bruner, 2000). To avoid these biases, we follow a revealed preference-based approach combined with administrative data.

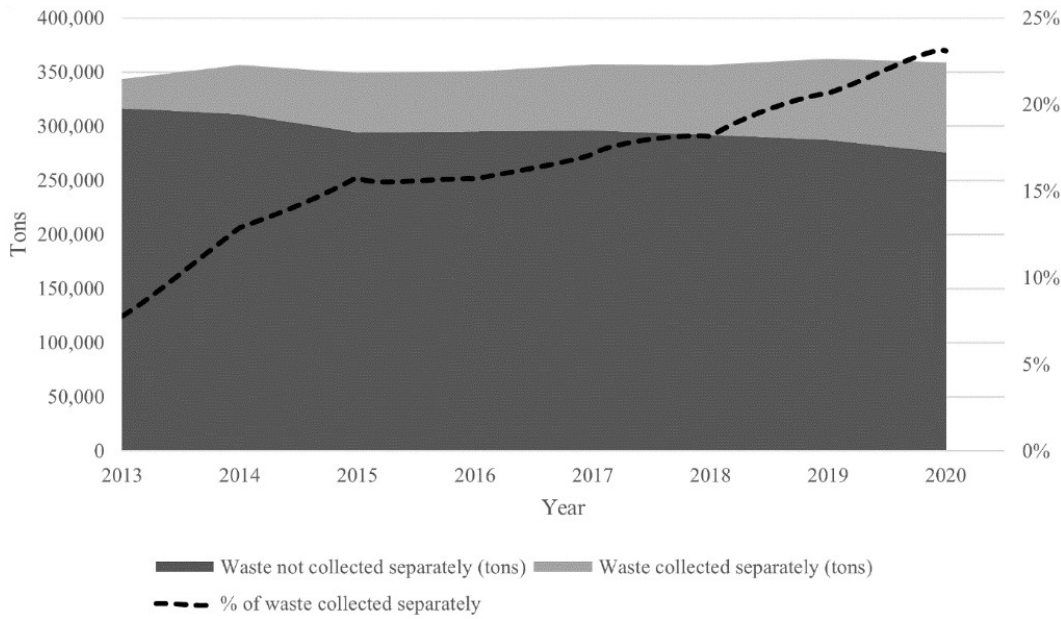
We measure political preferences using vote shares from elections for the European Parliament (EP) and municipal bodies in Budapest. More specifically, we use the vote distributions of the parties in EP elections and vote distributions of the mayoral candidates in municipal elections in 2014 and 2019. EP elections provide a suitable setting for the analysis because voters cast their vote for party lists and results are available for every district of Budapest. This was our primary data source. Mayoral election data are also utilized for a robustness check.³

Pro-environmental attitudes can be measured by involvement in different activities. One possible such activity that can be measured at the district level to reveal environmental preferences is waste separation. Aphale et al. (2015) and Grazhdani (2016) suggested that environmentally conscious individuals are more likely to engage in waste separation. The amount of waste collected separately and the recycling rate (the proportion of the separated waste within the total amount of waste) can serve as appropriate indicators of waste separation. Naturally, an increase in the volume of selective waste could reflect a general increase in waste production. Since the volume of communal waste did not increase in the period under analysis (2013-2020), while the waste collected separately increased substantially (Figure 4.1), in our analysis we use the amount of waste collected separately as a proxy for pro-environmental behavior.

EP and municipal elections are held every five years. The election-related data were obtained from the National Election Office. We used data only for the 2014 and 2019 EP and municipal elections since curbside waste separation has been available for all Budapest districts only since 2013 (the service is completely free of charge for the public, with no extra charge for either the bins or the collection of the waste). See the Appendix for the left-wing and right-wing classification of parties and mayoral candidates.

³Naturally, there are many factors influencing the election of a mayor, and several of them are connected to the candidate itself and not to the party nominating him or her (Soós and Kákai, 2011; Kákai and Vető, 2019). However, party preferences seem to influence citizens' choices. Hence, the vote shares of left- and right-wing candidates tend to mirror what would be party vote shares under a party vote system (Körösényi et al., 2017).

Figure 4.1: Amount of waste generated and collected separately in Budapest

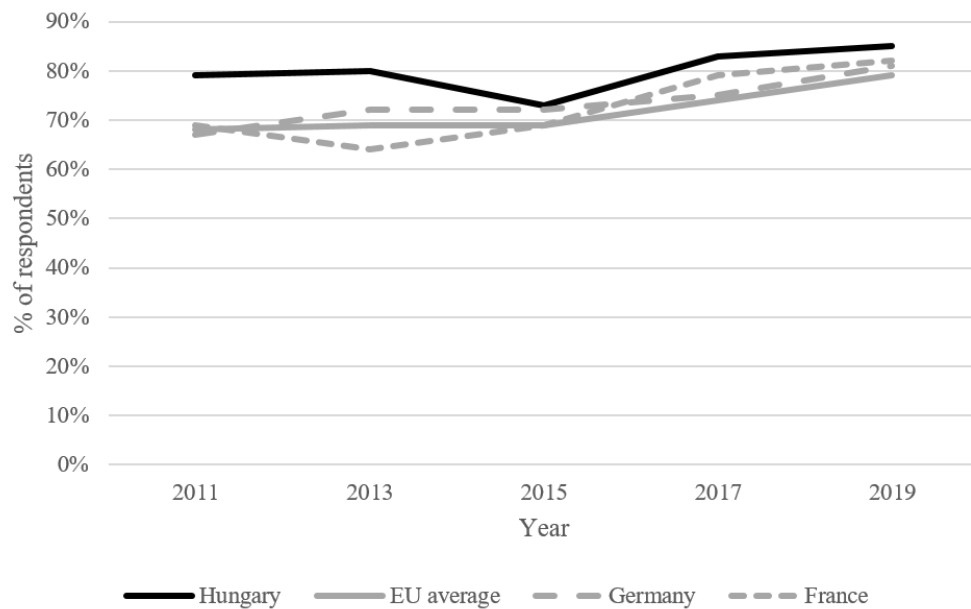


Data on separated waste was provided by the waste management company owned by the municipality of Budapest. The dataset includes the monthly amount of paper and plastic/metal waste at the district level (‘Islands’ remained available for glass, but this data was not utilized in this research). This data became available at the city level in April 2013; we included all data until August 2020. Each household was provided with at least one free bin for paper and another bin for plastic and metal waste. With the launch of curbside collection, it became mandatory to use these bins for recyclable waste and it has been prohibited to dispose of paper, plastic, or metal waste in regular bins. However, enforcing waste separation regulations is challenging and often non-existent in practice. Therefore, it can be argued that personal attitudes, rather than the law, drive involvement in waste separation. Once the curbside waste collection system was deployed, waste separation ‘islands’ were removed for paper and plastic/metal. Note that data on voting aggregate individual choices, while data on waste generation aggregate household-level behavior. However, it is well established in the political science literature that political preferences within households tend to be relatively homogeneous (Abendschön and Elff, 2006; Alford et al., 2011; Hatemi et al., 2014). To make the waste generation data proportional to the population of the district, we calculated per

capita values based on population data published by the Hungarian Central Statistical Office (KSH).

As waste generation is largely determined by income (Johnstone and Labonne, 2004; Talalaj and Walery, 2015) and population density (Owusu et al., 2013; Lardinois and Furedy, 1999), it is necessary to control for these factors. Since waste generation is influenced by household income, district-level average income might not capture all the relevant information. Hence, we included data for average taxable income, calculated at 2013 constant prices using the Hungarian consumer price index published by the KSH. We also included the percentage (in terms of the total resident population) of jobseekers registered for more than 180 days, the percentage of residents aged above 65, and the percentage of people eligible for public healthcare subsidy in order to capture the bottom of the income distribution that is often less engaged with waste separation (Owusu et al., 2013). Population density was captured by the number of people per dwelling. All district-level data were obtained from the regional database of the KSH and from the National Regional Development and Spatial Planning Information System.

Figure 4.2: Share of respondents indicating climate change as a serious problem



The time horizon of our analysis spans 2013 to 2020. This time window is particularly relevant because sustainability as an issue became significantly more important to Hungarian citizens after 2015 as indicated by the Eurobarometer climate change surveys (see Figure 4.2). The descriptive statistics of the dataset used in this study are shown in Table 4.1.

Since in our panel dataset political attitudes are measured only twice (2014 and 2019), waste separation data and the control variables are also aggregated to district-level averages for 2013-2014 and 2018-2019. We use two-year intervals instead of one month data, as the latter might be affected by one-time events. As a robustness check, we performed the same analysis using data only for 2014 and 2019.

The estimated equation is as follows:

$$Left_{it} = \beta_0 + \beta_1 Waste_{it} + \beta_2 X_{it} + 2019_t + c_i + u_{it} \quad (4.1)$$

where $Left_{it}$ refers to the vote share of the left-wing candidates in election t in district i , $Waste_{it}$ is the per capita waste collected separately in district i around election t , X_{it} contains the control variables described above for district i around election t , 2019_t is a dummy variable for the election of 2019 that is included to control for the overall changes in political preferences from 2014 to 2019, c_i is the district fixed effect for district i , and u_{it} is the idiosyncratic error term.

The equation is estimated using fixed effects or random effects regression method depending on the results of the Hausman test. Finally, standard errors are clustered by district.

Table 4.1: Descriptive statistics of the variables (annual district-level data)

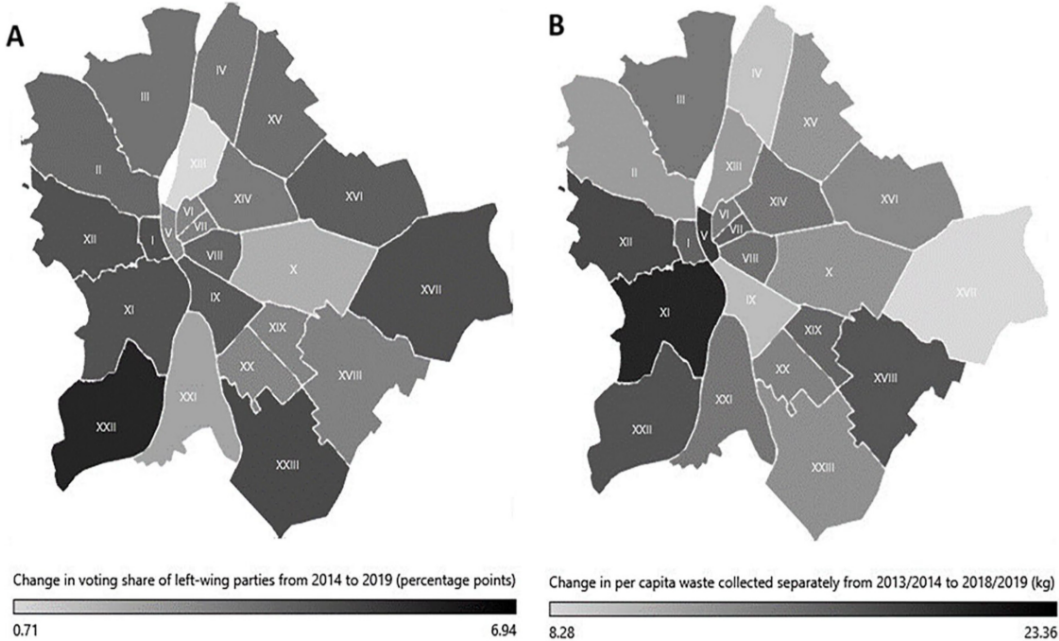
Variable	Obs.	Mean	St. dev.	Median	Min	Max
Vote share of the right-wing parties in the EP elections (%)	46	50.9	5.5	51.1	36.2	60.5
Vote share of the left-wing parties in the EP elections (%)	46	47.0	4.3	46.9	39.1	59.6
Vote share of the right-wing parties in the municipal elections (%)	46	50.2	10.4	51.4	18.1	71.0
Vote share of the left-wing parties in the municipal elections (%)	46	46.0	11.7	46.3	6.6	81.9
Waste collected separately (kg/capita)	183	19.0	8.1	19.7	0.5	38.4
Average taxable income (2013 prices, million HUF/local resident)	184	1.47	0.35	1.43	0.83	2.50
Jobseekers registered for more than 180 days (% of total population)	184	0.68	0.41	0.58	0.17	2.60
Population aged above 65 (% of total population)	184	20.5	2.9	20.0	15.4	26.8
Eligible for public healthcare subsidy (% of total population)	184	1.59	0.47	1.59	0.58	3.00
Number of people per dwelling (capita)	184	1.94	0.39	2.00	1.27	2.72

4.4 Results

When we compare the results of the 2014 and the 2019 elections, it is evident that the left-wing parties have gained ground (see Figure 4.3). While a left-leaning mayoral candidate won in only five districts (out of 23) in 2014, left-wing candidates won in 14 districts in 2019. At the same time, the issue of sustainability has become more important to citizens (see Figure 4.2).

This might suggest that pro-environmental behavior and political preferences are connected to each other, as observed in most Western countries. However, regression results (Table 4.2) indicate a different picture. Since the amount of per capita waste collected separately has a negative coefficient, it indicates that left-wing parties in Budapest generally won a lower percentage of votes in districts where waste separation gained momentum, and their support increased more in districts where waste separation did not increase that much (Figure 4.3).

Figure 4.3: Change in voting share of left-wing parties (panel A) and per capita waste collected separately (panel B) from 2014 to 2019 in the districts of Budapest



Note: Numbers indicate districts.

All four regressions suggest similar main effects, namely, that a positive shift in pro-environmental behavior seems to have favored right-wing parties. The estimated waste separation parameter is negative and statistically significant; that is, in districts where waste separation increased more substantially, the increase in the vote share of left-wing parties was lower for both the EP and the municipal elections. However, the effect size seems to be much greater for municipal elections (with lower significance) indicating that citizens may vote differently in a local election than in a European one.

Table 4.2: Regression results (dependent variable: vote share of left-wing parties)

Variables	EP elections		Municipal elections	
	Two-year data	One-year data	Two-year data	One-year data
Waste collected separately	-0.107 (0.051)	-0.091** (0.035)	-0.661 (0.353)	-0.424 (0.230)
Average taxable income	3.318 (2.250)	3.681 (1.986)	-11.594 (37.976)	3.478 (23.523)
Jobseekers registered for more than 180 days	2.065 (1.174)	1.553 (1.050)	-4.367 (2.322)	-7.517 (6.223)
Population aged above 65	-0.313* (0.151)	-0.406** (0.141)	0.068 (0.946)	-0.098 (1.325)
Eligible for public healthcare subsidy	-1.925** (0.741)	-1.290* (0.646)	-4.181 (3.438)	-3.430 (1.672)
Number of people per dwelling	-4.072** (1.495)	-4.361** (1.586)	221.373* (87.850)	140.107* (55.634)
Year 2019	5.987*** (1.838)	4.593** (1.579)	27.040 (27.563)	10.778 (15.486)
N	46	46	46	46
Number of districts	23	23	23	23
Adjusted R ²	0.502	0.463	0.792	0.738

Notes: Random effects models for the European Parliamentary elections and fixed effects models for the municipal elections data based on the Hausman test. Standard errors (in parentheses) are clustered by district.

According to Table 4.2, there are much larger differences in the results for municipal elections than for EP elections. This suggests that party-list based voting shares, with the majority of the parties running independently, are more stable, yet even in these cases, right-wing parties performed better in districts where waste separation is more important for the citizens.

4.5 Discussion

Our results can be interpreted in various ways. First, it could be that certain “environmentally conscious” practices are so uncontroversial in Budapest (or generally in Hungary) that it is hard to create political divisions along them. This in itself does not explain why right-leaning voters appear to be more environmentally conscious. Another possible explanation might be that Hungarians care less about the environment than citizens in Western Europe, and hence neither political side leverages the issue, making the traditional left-right divide over this issue irrelevant. However, according to the Eurobarometer surveys, Hungarians seem to care more about the environment than Western Europeans (Figure 4.2). Furthermore, even if this argument holds, it still does not explain the difference that we find in our analysis.

Apart from environmental attitudes, other factors might drive our results. First, as research suggests, it is possible that right-leaning individuals are more obedient toward authority (Graham et al., 2009), and since waste separation is compulsory by law they comply with it as much as possible.⁴ Another possible explanation could be that peer pressure that might incentivize waste separation is stronger in low-density neighborhoods (Brueckner and Largey, 2008), which happen to be the more right-leaning areas in Budapest. Among others, Ari and Yilmaz (2016), Videras et al. (2012), and Welsch and Kühling (2015) provide evidence on social interaction effects in pro-environmental behavior. Individuals are more likely to collect waste separately or engage in other behavior that is regarded as environmentally friendly when their friends or neighbors do so. Likewise, individuals are less likely to display pro-social attitudes, including environmental consciousness, when others are less pro-social, or when others do not monitor their behavior. Thus, any initial difference in environ-

⁴It is important to note that although waste separation is compulsory, enforcing the rule is rather difficult, if not impossible in practice.

mental attitudes between individuals of different political persuasions is likely to be magnified by social multiplier effects (Glaeser et al., 2003). Even if left and right leaning voters are equally environmentally conscious, greater peer pressure in one group can lead to observed differences in pro-environmental behavior and attitudes.

This interpretation is supported by the inclusion of the interaction term of waste collection and the number of people per dwelling in the regression model, which yields positive coefficients. However, these are only significant for the EP elections using two-year data. This indicates that in districts where houses and flats are more crowded (i.e., monitoring the behavior of others may be more challenging), there is a weaker correlation between pro-environmental behavior and support for right-wing parties. The detailed results are presented in Table A.6 of the appendix.

A higher level of human capital, such as greater educational attainment, could also contribute to pro-environmental behavior. Although this could be due to selection effects, several studies (e.g., Meyer, 2015; Ponce et al., 2019; Hoffmann and Mutarak, 2020) found that there is likely a causal relationship: more education increases environmental consciousness. This could be simply due to more information being available to more highly educated individuals but also due to an attitude change in response to education. However, more highly educated individuals are more likely to be wealthier and live in wealthier neighborhoods. By controlling for taxable income, we partially captured this effect.

Perhaps the most promising explanation for our results is that in post-communist countries, being environmentally friendly is less connected, if at all, to left-wing politics. First, socialist regimes built up many “dirty industries” (Pál, 2023). This may have limited the extent to which the connotations of left-wing politics and environmentalism could align. Yet, as Gille (2007) or Pál (2023) argue, socialist regimes also heavily promoted recycling which adds nuance to this reasoning. Second, according to the 2019 special Eurobarometer report on climate change, climate change is viewed as a more serious problem by younger respondents than by older respondents. The left-wing social environment, consisting of older left-wing voters and politicians socialized in the communist regime, has not constituted fertile ground for environmentalist ideas. This reasoning is supported by the European Social Survey Round 9 data, according to which there is a significant correlation between age and

political attitudes. However, the sign of the correlation is different for Western and Eastern Europe, with a coefficient of 0.085 for Western Europe and -0.078 for the post-communist bloc, where the negative value indicates a more left-leaning orientation. That is, while younger people are more likely to have a left-leaning orientation in Western Europe, this age cohort is more likely to be right-leaning in Eastern Europe. At the same time, right-wing political narratives, defined primarily by cultural identities, often harkened back to the period before the Second World War, where a reverence for nature was often a key element of right-wing community organization (Jehlička and Jacobsson, 2021). This reasoning is consistent with the findings of McCright et al. (2015), which suggest that left and right have different meanings in Western Europe and Eastern Europe.

Our main contribution to the literature on political preferences and environmental attitudes is that we do not use survey data, unlike most studies in the literature. Answers to survey questions might not reflect actual behavior; hence, we have chosen to rely not on stated but on revealed preferences. Note, however, that the simple observation that an individual collects waste separately does not necessarily mean that she/he is more environmentally conscious *in general*. It does mean, however, that it is important enough for her/him to act in a pro-environmental manner, at least in the case of waste collection. This may be due to internal motivation, social pressure, or both. Whatever may be the explanation, pro-environmental attitudes are seemingly associated less with left-wing politics in Hungary than in most Western countries.

One objection to our argument could be that while left-leaning voters engage less in waste separation, they may produce less waste in the first place. For this to be true, a substantial number of households in left-leaning districts would have to produce less waste for the difference to be measurable at the district level, and at the same time, a substantial number of households in right-leaning districts would have to produce more waste, because the total amount of waste has been mostly constant at the city level, as we have already pointed out earlier (see Figure 4.1). This possibility is unlikely, as waste generation is driven mostly by income, and the trends in average taxable income show similar trends across districts in the period under consideration. Furthermore, and even more importantly, if left-leaning individuals have cut their waste generation, they would have been more likely to decrease their non-recyclable waste, which could have led to an increase in not only the ratio

but also the volume of selectively collected waste. Thus, overall, we consider the above scenario implausible.

An important, and perhaps obvious, limitation of our study is that elections are held only every five years; therefore, it is not possible to construct a continuous dataset for political preferences. We could have added polling data to the dataset, but polling data are often not aligned with true preferences. We could also have added the results of national elections from 2014 and 2018, but the constituency boundaries for municipal/EP and national elections do not coincide. Furthermore, we used data only from 2013, as this was the year when curbside waste separation was extended to the whole territory of Budapest. We believe, however, that the revealed lack of connection between environmentalism and left-wing politics in Budapest can be generalized to the wider Hungarian context and perhaps to post-communist Central and Eastern European countries, as can also be inferred from McCright et al. (2015).

Another limitation arises from the nature of the data used for this study. Since reliable individual-level election data are not available, we relied on district-level aggregates in our analysis. Therefore, our results reveal patterns of behavior for the majority of individuals within a district, not specific individuals. However, election data are arguably the most reliable measure one can have of political preferences.

Until recently, left-wing parties in Hungary have shown only limited interest in environmental issues based on the Manifesto Project data (Lehmann et al., 2023), despite the relatively favorable conditions for voter interest in environmental sustainability (Kovarek and Littvay, 2019). However, there are recent signs of change, and Hungarian left-wing parties may also converge with international left-wing trends in this area. Therefore, it is possible that in the future, we will see more stereotypical right-wing and left-wing attitudes towards environmental issues in Hungary, as in other Western countries.

4.6 Conclusions

In this article, we studied the relationship between political preferences and pro-environmental behavior. Political preferences were measured by vote shares of left-wing and right-wing parties in EP and municipal elections in Budapest, Hungary, while we captured pro-environmentalism by the volume

of curbside waste separation. Previous research suggests that the link between political and environmental attitudes in post-communist Central and Eastern European countries might differ from those in other developed nations. Specifically, an analysis based on survey data suggested that environmentalism is less connected to left-wing politics in Central and Eastern Europe (McCright et al., 2015). Our analysis, based on revealed instead of stated preferences, confirms this result. Using a panel dataset and applying fixed and random effects models, we found that waste separation is negatively correlated with the left-wing vote share; that is, in left-leaning districts individuals engage less in waste separation.

We proposed several possible explanations to account for our results. As the left-right political landscape is changing across Central and Eastern Europe, the effect of political preferences on pro-environmentalism remains a fertile ground for future research.

Policy Implications

Behavioral responses and rebound effects

A shift in consumer habits was observed during the pandemic. A positive development is the increase in the amount of separately collected waste, despite the unknown level of contamination. In contrast, the decrease in non-selective waste has not been equivalent to, or even less than, the increase in selective waste. This suggests that current waste collection systems do not necessarily reduce the overall amount of waste. This discrepancy points to the phenomenon known as the *circular rebound effect* (Maier et al., 2023), where improved waste sorting infrastructure creates a false sense of environmental responsibility, potentially encouraging increased consumption.

For waste management authorities, this implies that technological upgrades in collection infrastructure must be complemented by behavioral interventions and education campaigns aimed at reducing total material throughput, not merely reallocating it between waste streams. Moreover, communication strategies should emphasize the distinction between recycling and absolute waste reduction, correcting the public misconception that increased recycling alone constitutes environmental progress. Local governments should collaborate with NGOs and educational institutions to develop behaviorally informed nudges and incentives, targeting specific demographic groups most prone to rebound effects.

The findings of this study suggest that door-to-door selective waste collection systems, while effective in increasing recycling volumes, may induce unintended behavioral responses that elevate total waste generation. As a result, infrastructure-based interventions must be carefully calibrated to avoid counterproductive environmental outcomes.

First, it is recommended that selective collection infrastructure be implemented in conjunction with behavioral communication strategies. The presence of easily accessible collection systems may lower perceived environmental costs and weaken intrinsic motivations to reduce waste. Therefore, informational campaigns that emphasize waste prevention—not just separation—should be designed and delivered alongside infrastructure rollout. Messaging should counteract the perception that recycling alone constitutes environmentally responsible behavior and instead reinforce waste minimization as the primary objective.

Second, waste composition monitoring should be institutionalized to detect rebound effects in real time. Although increases in selectively collected volumes may be viewed as positive indicators, they may conceal broader patterns of material overuse or contamination. Routine audits of waste streams, particularly in newly serviced municipalities, are necessary to assess whether infrastructure is producing net sustainability gains or simply shifting public perceptions. These insights can inform adaptive adjustments in service design.

Infrastructure and spatial inequality

The results also underscore the importance of differentiated waste management strategies based on settlement size and infrastructure availability. Urban municipalities, particularly those equipped with dual-bin systems and curbside collection, achieved higher increases in selective waste, suggesting that logistical convenience is a major driver of recycling participation. In contrast, rural settlements struggled to match this performance, highlighting the critical need to expand and modernize infrastructure in underserved areas.

Policymakers should consider targeted investment in door-to-door collection systems and standardized bin provision in small municipalities, as well as the deployment of mobile collection services where fixed infrastructure is not feasible. Additionally, infrastructural upgrades must be accompanied by training programs for local authorities and waste workers to ensure proper implementation and reduce operational inefficiencies. Investment decisions should be informed by spatially disaggregated data, enabling the allocation of

resources to areas with the greatest unmet needs and lowest recycling performance.

Infrastructure effectiveness is context-dependent, and policies must be tailored to local socioeconomic conditions. In municipalities where environmental awareness is low or participation in waste sorting remains limited, additional investments in education and transparency may be required before infrastructure can yield meaningful behavioral shifts.

Financial and regulatory instruments

The persistent rise in total waste, regardless of improvements in recycling, calls for a broader shift toward consumption-based policies. Strategies such as extended producer responsibility (EPR), eco-design regulations, and packaging taxes could play an increasingly vital role in limiting waste generation at the source. Fiscal tools can also incentivize households to reduce mixed waste.

In parallel, municipal governments should adopt performance-based funding schemes that reward waste reduction rather than only recycling rates, thus aligning economic incentives with environmental goals. Policymakers should pilot differential waste tariffs or pay-as-you-throw (PAYT) schemes, particularly in urban areas where waste monitoring technologies can be more easily deployed. These financial mechanisms, if transparently implemented, can foster a stronger link between individual behavior and environmental outcomes, while maintaining social equity through exemptions or subsidies for low-income households.

Incentives and penalties can also promote waste reduction (Cossu and Masiaste, 2013), as long as policy implementation is open, simple, and based on societal needs. In particular, financial incentives can significantly increase recycling rates (Kuo and Perrings, 2010). Well-structured incentives can maintain high levels of participation in waste management programs (Li et al., 2017; Mu and Zhang, 2021; Zhang et al., 2022), but they need to be carefully calibrated to avoid unintended consequences such as increased contamination rates (Shaw and Maynard, 2008; Taylor, 2000; Vorobeva and Wang, 2022; De Jaeger et al., 2011). In this context, the introduction of a RePont redemption scheme to reduce plastic waste seems an exciting experiment.

Data-driven governance

This research's insights reinforce the need for integrated data systems and real-time monitoring of waste flows. The pandemic highlighted the fragility and fragmentation of municipal data reporting in many regions. Effective policy requires access to granular, temporally detailed, and standardized waste data to support timely interventions.

National governments and the EU should invest in digital infrastructure that enables municipalities to track waste composition and contamination rates, while also providing public transparency dashboards. These steps would enable adaptive waste governance—critical for resilience not only during public health emergencies but also in the face of ongoing ecological challenges. Linking waste data with sociodemographic and consumption databases could improve the targeting of interventions and allow for predictive analytics in anticipating future surges in waste generation. Developing standardized indicators across member states would further enhance the comparability and scalability of successful waste management policies within the EU framework.

Political preferences and targeted communication

Understanding the political preferences that influence environmental behavior may also be key to designing and implementing effective waste management programs. The results suggest that political ideologies may lead to different attitudes toward environmental issues, meaning that tailored communication strategies targeting specific social groups may be more effective than generic campaigns.

For conservative social groups, for example, the economic and local benefits of environmental protection should be emphasized, such as how separate waste collection improves the quality of life and economic situation of the local community. For more liberal groups, global environmental impacts, such as combating climate change, may be the main motivating factor.

Given the differences in political preferences, policymakers need to develop policies that convey attractive messages to both sides. It is also becoming clear that political polarization can hamper coherent environmental action

programs. Therefore, policies need to be transparent to avoid criticism embedded in political narratives and to ensure that social trust in institutions is increased. The findings suggest that the effectiveness of environmental programs can be enhanced by shaping them to reflect societal values and political attitudes, while emphasizing common goals that appeal to both sides. In addition to general information, education and outreach campaigns could focus on community interests, long-term economic benefits, and local outcomes.

Bibliography

- Abbas, F. and Lamri, N. (2025). Optimization of Solid Waste Valorization in Algeria: Challenges and Sustainable Solutions. *Bulletin of the Serbian geographical society*, 105(1):287–304.
- Abbott, A., Nandeibam, S., and O’Shea, L. (2011). Explaining the variation in household recycling rates across the UK. *Ecological Economics*, 70(11):2214–2223.
- Abendschön, S. and Elff, M. (2006). Alan S. Zuckerman (Hg.): The social logic of politics. Personal networks as contexts for political behavior. *Politische Vierteljahresschrift*, 47(2):333–334.
- Abirrached Fernández, M. T., Torres Ríos, J., and Dettmer García, J. O. (2021). Hábitos de consumo modificados durante la pandemia de COVID-19. *Realidad Empresarial*, (11):16–22.
- Aday, S. and Aday, M. S. (2020). Impact of COVID-19 on the food supply chain. *Food Quality and Safety*, 4(4):167–180.
- Adelodun, B., Ajibade, F. O., Ibrahim, R. G., Ighalo, J. O., Bakare, H. O., Kumar, P., Eid, E. M., Kumar, V., Odey, G., and Choi, K. (2021). Insights into hazardous solid waste generation during COVID-19 pandemic and sustainable management approaches for developing countries. *Journal of Material Cycles and Waste Management*, 23(6):2077–2086.
- Adibfar, A., Gulhare, S., Srinivasan, S., and Costin, A. (2022). Analysis and modeling of changes in online shopping behavior due to COVID-19 pandemic: a Florida case study. *Transport Policy*, 126:162–176. DOI: <https://doi.org/10.1016/j.tranpol.2022.07.003>.

- Aggarwal, P. (2021). Plastic production and waste generation during the COVID-19 pandemic. *International Journal of Social Science and Economic Research*, 6(6):1795–1806.
- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2):179–211.
- Alford, J. R., Hatemi, P. K., Hibbing, J. R., Martin, N. G., and Eaves, L. J. (2011). The politics of mate choice. *The Journal of Politics*, 73(2):362–379.
- Amaral, N. B., Chang, B., and Burns, R. (2022). Understanding consumer stockpiling: Insights provided during the COVID-19 pandemic. *Journal of Consumer Affairs*, 56(1):211–236.
- Amaya, J. L., Hidalgo, J., Jervis, F., and Moreira, C. (2019). Influence of socio-economic factors on household solid waste (HSW) generation of the city of Guayaquil, Ecuador. In *Proceedings of the 17th LACCEI International Multi-Conference for Engineering, Education, and Technology: "Industry, Innovation, and Infrastructure for Sustainable Cities and Communities"*.
- Ammendolia, J., Saturno, J., Brooks, A. L., Jacobs, S., and Jambeck, J. R. (2021). An emerging source of plastic pollution: Environmental presence of plastic personal protective equipment (PPE) debris related to COVID-19 in a metropolitan city. *Environmental Pollution*, 269:116160.
- Ando, A. W. and Gosselin, A. Y. (2005). Recycling in multifamily dwellings: Does convenience matter? *Economic Inquiry*, 43(2):426–438.
- Angrist, J. D. and Pischke, J.-S. (2009). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton University Press.
- Antonio, R. J. and Brulle, R. J. (2011). The unbearable lightness of politics: Climate change denial and political polarization. *The Sociological Quarterly*, 52(2):195–202.
- Aphale, O., Thyberg, K. L., and Tonjes, D. J. (2015). Differences in waste generation, waste composition, and source separation across three waste districts in a New York suburb. *Resources, Conservation and Recycling*, 99:19–28.

- Ari, E. and Yilmaz, V. (2016). A proposed structural model for housewives' recycling behavior: A case study from Turkey. *Ecological Economics*, 129:132–142.
- Arora, N., Robinson, K., Charm, T., Grimmelt, A., Ortega, M., Staack, Y., Whitehead, S., and Yamakawa, N. (2020). Consumer sentiment and behavior continue to reflect the uncertainty of the COVID-19 crisis. McKinsey & Company, July 8, 2020.
- Bakó, B., Berezvai, Z., Isztin, P., and Ráti, J. (2025). Is it Greener on the Right Side? The Relationship between Political Preferences and Environmental Behavior in Hungary. *East European Politics and Societies*.
- Bandara, N. J., Hettiaratchi, J. P., Wirasinghe, S. C., and Pilapiiya, S. (2007). Relation of waste generation and composition to socio-economic factors: A case study. *Environmental Monitoring and Assessment*, 135(1-3):31–39.
- Barnett, H. J. and Morse, C. (1963). *Scarcity and Growth: The Economics of Natural Resource Availability*. The Johns Hopkins Press.
- Barr, S., Ford, N. J., and Gilg, A. W. (2003). Attitudes towards recycling household waste in Exeter, Devon: Quantitative and qualitative approaches. *Local Environment*, 8(4):407–421.
- Beaney, T., Clarke, J. M., Jain, V., Golestaneh, A. K., Lyons, G., Salman, D., and Majeed, A. (2020). Excess mortality: the gold standard in measuring the impact of COVID-19 worldwide? *Journal of the Royal Society of Medicine*, 113(9):329–334.
- Behera, B. C. (2021). Challenges in handling COVID-19 waste and its management mechanism: A Review. *Environmental Nanotechnology, Monitoring & Management*, 15:100432.
- Bennagen, M. E. C., Nepomuceno, G., and Covar, R. (2002). Solid Waste Segregation and Recycling in Metro Manila: Household Attitudes and Behavior. *EEPSEA Research Report*, (rr2002062).
- Benson, N. U., Bassegy, D. E., and Palanisami, T. (2021). COVID pollution: Impact of COVID-19 pandemic on global plastic waste footprint. *Heliyon*, 7(2):e06343.

- Bergado, J. R., Persello, C., Reinke, K., and Stein, A. (2021). Predicting wild-fire burns from big geodata using deep learning. *Safety Science*, 140:105276.
- Bernstad, A., la Cour Jansen, J., and Aspegren, A. (2013). Door-stepping as a strategy for improved food waste recycling behaviour – Evaluation of a full-scale experiment. *Resources, Conservation and Recycling*, 73:94–103.
- Best, H. and Kneip, T. (2011). The impact of attitudes and behavioral costs on environmental behavior: A natural experiment on household waste recycling. *Social Science Research*, 40:917–930.
- Bhatti, A., Akram, H., Basit, H. M., Khan, A. U., Raza, S. M., and Naqvi, M. B. (2020). E-commerce trends during COVID-19 Pandemic. *International Journal of Future Generation Communication and Networking*, 13(2):1449–1452.
- Bishop, R. C., Kelso, M. M., Krutilla, J. V., and Fisher, A. C. (1976). The economics of natural environments: Studies in the valuation of commodity and amenity resources. *Land Economics*, 52(4):567.
- Boldero, J. (1995). The prediction of household recycling of newspapers: The role of attitudes, intentions, and situational factors. *Journal of Applied Social Psychology*, 25(5):440–462.
- Boström, M. (2021). Take the opportunity afforded by the COVID-19 experiences: progressive non-growth policies for sustainable lifestyles. *Frontiers in Sustainability*, 2:726320. DOI: <https://doi.org/10.3389/frsus.2021.726320>.
- Brontowiyono, W. (2021). Ecological mitigation and earth restoration strategies in the COVID-19 post-pandemic era. *ENDLESS: International Journal of Future Studies*, 4(2):298–309.
- Brueckner, J. K. and Largey, A. G. (2008). Social interaction and urban sprawl. *Journal of Urban Economics*, 64(1):18–34.
- Buheji, M. (2020). Psychological resilience and poor communities coping with COVID-19 pandemic. *International Journal of Psychology and Behavioral Sciences*, 10(4):100–108.

- Bączyk, M., Tunn, V., Worrell, E., and Corona, B. (2024). Consumer behavior in circular business models: Unveiling conservation and rebound effects. *Sustainable Production and Consumption*, 52:283–298.
- Cai, M., Guy, C., Héroux, M., Lichtfouse, E., and An, C. (2021). The impact of successive COVID-19 lockdowns on people mobility, lockdown efficiency, and municipal solid waste. *Environmental Chemistry Letters*, 19(6):3959–3965.
- Callaway, B. and Sant’Anna, P. H. C. (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics*, 225(2):200–230.
- Caprara, G. V., Schwartz, S., Capanna, C., Vecchione, M., and Barbaranelli, C. (2006). Personality and politics: Values, traits, and political choice. *Political Psychology*, 27(1):1–28.
- Castro, C. G., Trevisan, A. H., and Pigosso, D. C. A. (2022). The Rebound Effect of Circular Economy: Definitions, Mechanisms, and a Research Agenda. *Journal of Cleaner Production*, 331:130053.
- Chandra, J., Charpignon, M.-L., Bhaskar, A., Therriault, A., Chen, Y.-H., Mooney, A., Dahleh, M. A., Kiang, M. V., and Dominici, F. (2024). Excess Fatal Overdoses in the United States During the COVID-19 Pandemic by Geography and Substance Type: March 2020–August 2021. *American Journal of Public Health*, 114(6):599–609.
- Chen, C. (2021). Clarifying rebound effects of the circular economy in the context of sustainable cities. *Sustainable Cities and Society*, 66:102622.
- Choo, E. K. and Rajkumar, S. V. (2020). Medication Shortages During the COVID-19 Crisis: What We Must Do. *Mayo Clinic Proceedings*, 95(6):1112–1115.
- Christina, M. M., Destyanto, T. Y., and Halim, L. (2023). Waste management of COVID-19 personal protective equipment in Indonesia and the potential for globally oriented development. *Jurnal Serambi Engineering*, 8(2).
- Clarke, D. and Tapia-Schythe, K. (2021). Implementing the panel event study. *The Stata Journal*, 21(4):853–884.

- Contreras-Contreras, P., Cuesta-Valiño, P., and Gutiérrez-Rodríguez, P. (2023). Happiness and its relationship to expectations of change and sustainable behavior in a post-COVID-19 world. *Journal of Management Development*, 42(6):458–482.
- Correia, S., Guimarães, P., and Zylkin, T. (2020). Fast Poisson Estimation with High-Dimensional Fixed Effects. *The Stata Journal*, 20(1):95–115.
- Cossu, R. and Masiaste (2013). Waste management policies in developing countries. *Waste Management*, 33(11):2487–2493.
- Costa, D., Fernandes, N., Arantes, J., and Keating, J. (2022). A dual-process approach to prosocial behavior under COVID-19 uncertainty. *PloS One*, 17(3):e0266050.
- Costa, D. L. and Kahn, M. E. (2013). Energy conservation "Nudges" and environmentalist ideology: Evidence from a randomized residential electricity field experiment. *Journal of the European Economic Association*, 11(3):680–702.
- De Jaeger, S., Eyckmans, J., Rogge, N., and Van Puyenbroeck, T. (2011). Waste management performance of states: Decentralization, regional diversity, and incentives. *Waste Management*, 31(4):759–769.
- de Medeiros, J. F., Marcon, A., Ribeiro, J. L. D., Quist, J., and D'Agostin, A. (2021). Consumer emotions and collaborative consumption: The effect of COVID-19 on the adoption of use-oriented product-service systems. *Sustainable Production and Consumption*, 27:1569–1588.
- DeBell, M. and Krosnick, J. A. (2009). Computing Weights for American National Election Study Survey Data. ANES Technical Report nes012427, American National Election Studies, Ann Arbor and Palo Alto.
- Démurger, S. (2001). Infrastructure development and economic growth: an explanation for regional disparities in China? *Journal of Comparative Economics*, 29(1):95–117.
- Deng, S., Wang, W., Xie, P., Chao, Y., and Zhu, J. (2020). Perceived severity of COVID-19 and post-pandemic consumption willingness: The roles of boredom and sensation-seeking. *Frontiers in Psychology*, 11.

- Derksen, L. and Gartrell, J. (1993). The social context of recycling. *American Sociological Review*, 58(3):434.
- Domenico, L. D., Safarzynska, K., and Raberto, M. (2022). Resource scarcity, circular economy and the energy rebound: A macro-evolutionary input-output model. *SSRN Electronic Journal*.
- Domina, T. and Koch, K. (2002). Convenience and frequency of recycling. *Environment and Behavior*, 34(2):216–238.
- Dunlap, R., Xiao, C., and McCright, A. M. (2001). Politics and environment in America: Partisan and ideological cleavages in public support for environmentalism. *Environmental Politics*, 10(4):23–48.
- Ekere, W., Mugisha, J., and Drake, L. (2009). Factors influencing waste separation and utilization among households in the Lake Victoria crescent, Uganda. *Waste Management*, 29(12):3047–3051.
- Enns, P. K., Lagodny, J., and Schuldt, J. P. (2017). Understanding the 2016 US presidential polls: The importance of hidden Trump supporters. *Statistics, Politics and Policy*, 8(1).
- European Commission (2024). Attitudes of Europeans towards the Environment 2024. Accessed: 2025-01-30.
- European Environment Agency (2024). Waste recycling in Europe - Recycling rates by country. Accessed: 2025-01-30.
- European Parliament and Council (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Waste Framework Directive). Accessed: 2025-05-25.
- Eva, N., Saputra, D. R., Wulandari, D. A., Yahya, F. A., and Annisa, W. (2021). Panic-buying behaviour during the COVID-19 outbreak: A cross-cultural psychological study. *KnE Social Sciences*.
- Evans, J. S. B. and Stanovich, K. E. (2013). Dual-process theories of higher cognition: Advancing the debate. *Perspectives on Psychological Science*, 8(3):223–241.

- Fadaei, A. (2021). Study of solid waste (municipal and medical) management during the COVID-19 pandemic: A review study. *Reviews on Environmental Health*, 37(4):559–566.
- Ferrara, P. (2025). Health risk factors, prevention, and inequalities. *Medicina*, 61(1):127.
- Feygina, I., Jost, J. T., and Goldsmith, R. E. (2009). System justification, the denial of global warming, and the possibility of “system-sanctioned change”. *Personality and Social Psychology Bulletin*, 36(3):326–338.
- Figge, F. and Thorpe, A. S. (2019). The symbiotic rebound effect in the circular economy. *Ecological Economics*, 163:61–69.
- Filho, W. L., Salvia, A. L., Sierra, J., Fletcher, C. A., Banks, C. E., Velazquez, L., Anholon, R., Rampasso, I. S., Maclean, C., Barbir, J., and Neiva, S. (2022). COVID-19 and households waste in Hispanic America: An assessment of trends. *Sustainability*, 14(24):16552.
- Filho, W. L., Voronova, V., Kloga, M., Paço, A., Minhas, A., Salvia, A. L., Ferreira, C. D., and Sivapalan, S. (2021). COVID-19 and waste production in households: A trend analysis. *Science of The Total Environment*, 777:145997.
- Fobissie, E. N. (2019). The role of environmental values and political ideology on public support for renewable energy policy in Ottawa, Canada. *Energy Policy*, 134:110918.
- Folz, D. H. (1991). Recycling program design, management, and participation: A national survey of municipal experience. *Public Administration Review*, 51(3):222–231.
- Frankish, K. (2010). Dual-process and dual-system theories of reasoning. *Philosophy Compass*, 5(10):914–926.
- Fricker, R. D. (2008). Sampling methods for web and E-mail surveys. In *The SAGE Handbook of Online Research Methods*, pages 195–216.
- Gamba, R. J. and Oskamp, S. (1994). Factors influencing community residents’ participation in commingled curbside recycling programs. *Environment and Behavior*, 26(5):587–612.

- Ganguly, R. K. and Chakraborty, S. (2023). Plastic waste management during and post Covid-19 pandemic: Challenges and strategies towards circular economy.
- Ganguly, R. K. and Chakraborty, S. K. (2021). Integrated approach in municipal solid waste management in COVID-19 pandemic: Perspectives of a developing country like India in a global scenario. *Case Studies in Chemical and Environmental Engineering*, 3:100087.
- Ganguly, R. K. and Chakraborty, S. K. (2024). Plastic waste management during and post Covid-19 pandemic: Challenges and strategies towards circular economy. *Heliyon*, 10(4):e25613.
- Geisendorf, S. and Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review*, 60(5):771–782.
- Geissdoerfer, M., Savaget, P., Bocken, N. M. P., and Hultink, E. J. (2017). The Circular Economy—A new sustainability paradigm? *Journal of Cleaner Production*, 143:757–768.
- Gershoff, E. T., Aber, J. L., Raver, C. C., and Lennon, M. C. (2007). Income is not enough: Incorporating material hardship into models of income associations with parenting and child development. *Child Development*, 78(1):70–95.
- Ghinea, C., Drăgoi, E. N., Comăniță, E.-D., Gavrilăscu, M., Câmpean, T., Curteanu, S., and Gavrilăscu, M. (2016). Forecasting municipal solid waste generation using prognostic tools and regression analysis. *Journal of Environmental Management*, 182:80–93.
- Gille, Z. (2007). From the Cult of Waste to the Trash Heap of History: The Politics of Waste in Socialist and Postsocialist Hungary. *Indiana University Press*.
- Glaeser, E. L., Sacerdote, B. I., and Scheinkman, J. A. (2003). The social multiplier. *Journal of the European Economic Association*, 1(2-3):345–353.
- González-Torre, P. L. and Adenso-Díaz, B. (2005). Influence of distance on the motivation and frequency of household recycling. *Waste Management*, 25(1):15–23.

- Goodman-Bacon, A. (2021). Difference-in-differences with variation in treatment timing. *Journal of Econometrics*, 225(2):254–277.
- Goulart Coelho, L. M., Lange, L. C., and Coelho, H. M. (2017). Multi-criteria decision making to support waste management: A critical review of current practices and methods. *Waste Management & Research*, 35(1):3–28.
- Graham, J., Haidt, J., and Nosek, B. A. (2009). Liberals and conservatives rely on different sets of moral foundations. *Journal of Personality and Social Psychology*, 96(5):1029–1046.
- Grazhdani, D. (2016). Assessing the variables affecting on the rate of solid waste generation and recycling: An empirical analysis in Prespa Park. *Waste Management*, 48:3–13.
- Gromet, D. M., Kunreuther, H., and Larrick, R. P. (2013). Political ideology affects energy-efficiency attitudes and choices. *Proceedings of the National Academy of Sciences*, 110(23):9314–9319.
- Groot, J. D. and Steg, L. (2007). General beliefs and the theory of planned behavior: The role of environmental concerns in the TPB. *Journal of Applied Social Psychology*, 37(8):1817–1836.
- Guerrero, L. A., Maas, G., and Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, 33(1):220–232.
- Gui, S., Zhao, L., and Zhang, Z. (2019). Does municipal solid waste generation in China support the environmental Kuznets curve? New evidence from spatial linkage analysis. *Waste Management*, 84:310–319.
- Guzzo, D., Walrave, B., Videira, N., Oliveira, I. C., and Pigosso, D. C. (2024). Towards a systemic view on rebound effects: Modelling the feedback loops of rebound mechanisms. *Ecological Economics*, 217:108050.
- Hage, O., Söderholm, P., and Berglund, C. (2009). Norms and economic motivation in household recycling: Empirical evidence from Sweden. *Resources, Conservation and Recycling*, 53(3):155–165.
- Hale, T., Angrist, N., Goldszmidt, R., Kira, B., Petherick, A., Phillips, T., Webster, S., Cameron-Blake, E., Hallas, L., Majumdar, S., and Tatlow, H.

- (2021). A global panel database of pandemic policies (Oxford COVID-19 government response tracker). *Nature Human Behaviour*, 5(4):529–538.
- Han, H. (2015). Travelers' pro-environmental behavior in a green lodging context: Converging value-belief-norm theory and the theory of planned behavior. *Tourism Management*, 47:164–177.
- Hantoko, D., Li, X., Pariatamby, A., Yoshikawa, K., Horttanainen, M., and Yan, J. (2021). Challenges and practices on waste management and disposal during COVID-19 pandemic. *Journal of Environmental Management*, 286:112140.
- Hassan, L. M., Shiu, E., and Parry, S. (2015). Addressing the cross-country applicability of the theory of planned behaviour (TPB): A structured review of multi-country TPB studies. *Journal of Consumer Behaviour*, 15(1):72–86.
- Hatemi, P. K., Medland, S. E., Klemmensen, R., Oskarsson, S., Littvay, L., Dawes, C., Verhulst, B., McDermott, R., Norgaard, A. S., Klofstad, C., Christensen, K., Johannesson, M., Magnusson, P. K. E., Eaves, L. J., and Martin, N. G. (2014). Genetic influences on political ideologies: Twin analyses of 19 measures of political ideologies from five democracies and genome-wide findings from three populations. *Behavior Genetics*, 44(3):282–294.
- Haupt, M., Vadenbo, C., and Hellweg, S. (2016). Do we have the right performance indicators for the circular economy?: Insight into the Swiss waste management system. *Journal of Industrial Ecology*, 21(3):615–627.
- Hemmesch, A. R., Bogart, K. R., and Barnes, E. (2025). "Lack" and "Finally": A qualitative analysis of barriers and facilitators in rare disease healthcare. *International Journal of Environmental Research and Public Health*, 22(1):117.
- Henry, R. K., Yongsheng, Z., and Jun, D. (2006). Municipal solid waste management challenges in developing countries – Kenyan case study. *Waste Management*, 26(1):92–100.
- Hidalgo-Crespo, J. and Amaya-Rivas, J. (2024). Citizens' pro-environmental behaviors for waste reduction using an extended theory of planned behavior in Guayas province. *Cleaner Engineering and Technology*, 21:100765.

- Hirsch, F. (1976). *Social Limits to Growth*. Harvard University Press.
- Hoffmann, R. and Muttarak, R. (2020). Greening through schooling: Understanding the link between education and pro-environmental behavior in the Philippines. *Environmental Research Letters*, 15(1):014009.
- Hong, K., Dragan, K., and Glied, S. (2019). Seeing and hearing: The impacts of New York City’s universal pre-kindergarten program on the health of low-income children. *Journal of Health Economics*, 64:93–107.
- Hu, S., Jia, X., Zhang, X., Zheng, X., and Zhu, J. (2017). How political ideology affects climate perception: Moderation effects of time orientation and knowledge. *Resources, Conservation and Recycling*, 127:124–131.
- Hungarian Central Statistical Office (2025a). Hungarian Central Statistical Office.
- Hungarian Central Statistical Office (2025b). Statistical Database on Waste Collection (2012–2023). Accessed: 2025-05-25.
- Hungarian Government (2012). Act CLXXXV of 2012 on Waste. Accessed: 2025-01-30.
- Ibrahim, S. (2020). Waste management in Balikpapan city based on circular economy. In *Waste Management as Economic Industry Towards Circular Economy*, pages 11–16.
- Ibáñez, M. V., Prades, M., and Simó, A. (2011). Modelling municipal waste separation rates using generalized linear models and beta regression. *Resources, Conservation and Recycling*, 55:1129–1138.
- Iimuro, M. and Tabata, T. (2023). Relationship between the demand for food delivery and takeaway services and the associated plastic packaging waste during the COVID-19 pandemic. *Journal of Material Cycles and Waste Management*, 26(1):591–601.
- Ikhlas, N., Miftahadi, M. F., Wibowo, Y. G., Ramadan, B. S., and Rachman, I. (2023). Waste management during COVID-19 pandemic: Could it be time-bomb. *International Journal of Environment and Waste Management*, 1(1):1.

- Imai, K. and Kim, I. S. (2021). On the use of two-way fixed effects regression models for causal inference with panel data. *Political Analysis*, 29(3):405–415.
- Inglehart, R. (1971). The silent revolution in Europe: Intergenerational change in post-industrial societies. *American Political Science Review*, 65(4):991–1017.
- Iriarte, A., Gabarrell, X., and Rieradevall, J. (2009). LCA of selective waste collection systems in dense urban areas. *Waste Management*, 29(2):903–914.
- Islam, T., Pitafi, A. H., Arya, V., Wang, Y., Akhtar, N., Mubarik, S., and Xiaobei, L. (2021). Panic buying in the COVID-19 pandemic: A multi-country examination. *Journal of Retailing and Consumer Services*, 59:102357.
- Jagun, Z. T., Daud, D., Ajayi, O. M., Samsudin, S., Jubril, A. J., and Rahman, M. S. A. (2023). Waste management practices in developing countries: a socio-economic perspective. *Environmental Science and Pollution Research*, 30(55):116644–116655.
- Jakus, P. M., Tiller, K. H., and Park, W. M. (1997). Explaining rural household participation in recycling. *Journal of Agricultural and Applied Economics*, 29(1):141–148.
- Janoff-Bulman, R., Sheikh, S., and Hepp, S. (2009). Proscriptive versus prescriptive morality: Two faces of moral regulation. *Journal of Personality and Social Psychology*, 96(3):521–537.
- Jehlička, P. and Jacobsson, K. (2021). *The Importance of Recognizing Difference: Rethinking Central and East European Environmentalism*, volume 87. Political Geography.
- Jenkins, R. R., Martinez, S. A., Palmer, K., and Podolsky, M. J. (2003). The determinants of household recycling: A material-specific analysis of recycling program features and unit pricing. *Journal of Environmental Economics and Management*, 45(2):294–318.
- Johnstone, N. and Labonne, J. (2004). Generation of Household Solid Waste in OECD Countries: An Empirical Analysis Using Macroeconomic Data. *Land Economics*, 80:529–538.

- Jost, J. T., Glaser, J., Kruglanski, A. W., and Sulloway, F. J. (2003). Political conservatism as motivated social cognition. *Psychological Bulletin*, 129(3):339–375.
- Jumadewi, A., Putri, S. K., and Sasmita, Y. (2023). Preferensi makanan online Dan timbulan sampah plastik delivery masa pandemi COVID-19. *Jurnal SAGO Gizi dan Kesehatan*, 4(2):233.
- Kala, K., Bolia, N. B., and Sushil (2020). Effects of socio-economic factors on quantity and type of municipal solid waste. *Management of Environmental Quality: An International Journal*, 31(4):877–894.
- Kanda, W. and Kivimaa, P. (2020). What opportunities could the COVID-19 outbreak offer for sustainability transitions research on electricity and mobility? *Energy Research & Social Science*, 68:101666.
- Kellstedt, P. M., Zahran, S., and Vedlitz, A. (2008). Personal efficacy, the information environment, and attitudes toward global warming and climate change in the United States. *Risk Analysis*, 28(1):113–126.
- Khan, D., Kumar, A., and Samadder, S. (2016). Impact of socioeconomic status on municipal solid waste generation rate. *Waste Management*, 49:15–25.
- Kim, Y., Kang, J., and Chun, H. (2022). Is online shopping packaging waste a threat to the environment? *Economics Letters*, 214:110398.
- King, M. F. and Bruner, G. C. (2000). Social desirability bias: A neglected aspect of validity testing. *Psychology and Marketing*, 17(2):79–103.
- Kirchherr, J., Reike, D., and Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127:221–232.
- Kirkman, R. and Voulvoulis, N. (2017). The role of public communication in decision making for waste management infrastructure. *Journal of Environmental Management*, 203:640–647.
- Kollmuss, A. and Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, 8(3):239–260.

- Kontis, V., Bennett, J. E., Rashid, T., Parks, R. M., Pearson-Stuttard, J., Guillot, M., Asaria, P., Zhou, B., Battaglini, M., and Corsetti, G. (2020). Magnitude, demographics and dynamics of the effect of the first wave of the COVID-19 pandemic on all-cause mortality in 21 industrialized countries. *Nature Medicine*, 26(12):1919–1928.
- Kosinski, M., Matz, S. C., Gosling, S. D., Popov, V., and Stillwell, D. (2015). Facebook as a research tool for the social sciences: Opportunities, challenges, ethical considerations, and practical guidelines. *American Psychologist*, 70(6):543–556.
- Kovarek, D. and Littvay, L. (2019). *Where did all the environmentalism go? 'Politics can be different' (LMP) in the 2018 Hungarian Parliamentary Elections*, volume 28.
- KSH (2021). A hazai vásárlói magatartás változása a COVID-19-járvány első hullámában. Retrieved from KSH.
- Kumar, N., Sharma, P., and Kumar, P. (2024). Impact of COVID 19 pandemic on the environmental management Processes-3R's (Reduce, reuse and recycling) of plastic wastes. In *Plastic and the COVID-19 Pandemic*, pages 111–139.
- Kuo, T.-Y. and Perrings, C. (2010). Incentives and waste management. *Environmental Economics and Policy Studies*, 12(1):67–84.
- Kyriacou, A. P., Muinelo-Gallo, L., and Roca-Sagalès, O. (2019). The efficiency of transport infrastructure investment and the role of government quality: An empirical analysis. *Transport Policy*, 74:93–102.
- Kákai, L. and Vető, B. (2019). Állam vagy/es önkormányzat? : Adalékok az önkormányzati rendszer átalakításához. *Politikatudományi Szemle*, 28(1):17–41.
- Körösényi, A., Ondré, P., and Hajdú, A. (2017). A “Meteoric” career in Hungarian politics. In *Oxford Scholarship Online*.
- Lange, F., Brückner, C., Kröger, B., Beller, J., and Eggert, F. (2014). Wasting ways: Perceived distance to the recycling facilities predicts pro-environmental behavior. *Resources, Conservation and Recycling*, 92:246–254.

- Lardinois, I. and Furedy, C. (1999). *Source separation of household waste materials: Analysis of case studies from Pakistan, the Philippines, India, Brazil, Argentina and the Netherlands*. WASTE.
- Lebersorger, S. and Beigl, P. (2011). Municipal solid waste generation in municipalities: Quantifying impacts of household structure, commercial waste and domestic fuel. *Waste Management*, 31:1907–1915.
- Lee, C. S. and Lim, D. (2022). CNN-based inspection module for liquid carton recycling by the reverse vending machine. *Sustainability*, 14(22):14905.
- Lehmann, P., Beck, S., de Brito, M. M., Gawel, E., Groß, M., Haase, A., Lepenies, R., Otto, D., Schiller, J., and Strunz, S. (2021). Environmental sustainability post-Covid-19: Scrutinizing popular hypotheses from a social science perspective. *Sustainability*, 13(16):8679.
- Lehmann, P., Franzmann, S., Burst, T., Regel, S., Riethmüller, F., Volkens, A., Weßels, B., and Zehnter, L. (2023). The Manifesto Data Collection. Manifesto Project (MRG/CMP/MARPOR). Version 2023a. *Wissenschaftszentrum Berlin für Sozialforschung (WZB)*.
- Li, J. and Xu, G. (2022). Circular economy towards zero waste and decarbonization. *Circular Economy*, 1(1):100002.
- Li, X., Wang, Z., and Jiang, H. (2017). Waste reduction and recycling: Evidence from China. *Waste Management*, 70:243–256.
- Liang, Y., Song, Q., Wu, N., Li, J., Zhong, Y., and Zeng, W. (2021). Repercussions of COVID-19 pandemic on solid waste generation and management strategies. *Frontiers of Environmental Science & Engineering*, 15:1–18.
- Lowe, B. H., Bimpizas-Pinis, M., Zerbino, P., and Genovese, A. (2024). Methods to estimate the circular economy rebound effect: A review. *Journal of Cleaner Production*, 443:141063.
- Luhar, I., Luhar, S., and Abdullah, M. (2022). Challenges and impacts of COVID-19 pandemic on global waste management systems: A review. *Journal of Composites Science*, 6(9):271.
- Luney, C. and Little, C. (2021). 398 Theatre waste management and the impact of COVID-19. *British Journal of Surgery*, 108(Supplement2).

- Maalouf, A., Mavropoulos, A., and El-Fadel, M. (2020). Global municipal solid waste infrastructure: Delivery and forecast of uncontrolled disposal. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, 38(9):1028–1036.
- Mahpour, A., Baghestani, A., and Mollajani, M. (2024). The lasting legacy of COVID-19 on individual shopping decisions: Tracing the evolution of online shopping habits and its stability. *Transportation Planning and Technology*, 47(1):1–21.
- Mahyari, K. F., Sun, Q., Klemeš, J. J., Aghbashlo, M., Tabatabaei, M., Khoshnevisan, B., and Birkved, M. (2022). To what extent do waste management strategies need adaptation to post-COVID-19? *Science of The Total Environment*, 837:155829.
- Maier, J., Steigerwald, D., and Geyer, R. (2023). Curbside recycling increases household consumption. *Resources, Conservation and Recycling*, 199:107271.
- Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Rostkowski, P., Thorne, R., Colón, J., Ponsá, S., Al-Mansour, F., Anguilano, L., Krzyżyńska, R., López, I., Vlasopoulos, A., and Spencer, N. (2017). Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. *Energy*, 141:2013–2044.
- Manomaivibool, P., Srivichai, M., Unroj, P., and Dokmaingam, P. (2018). Chiang Rai Zero Waste: Participatory action research to promote source separation in rural areas. *Resources, Conservation and Recycling*, 136:142–152.
- Manowong, E. and Ogunlana, S. O. (2008). Critical factors for successful public hearing in infrastructure development projects: A case study of the on Nuch waste disposal plant project. *International Journal of Construction Management*, 8(1):37–51.
- Maró, Z. M., Török, A., and Czine, P. (2025). Examining consumer preferences for basic foodstuffs in a highly inflationary economic environment: The case of price-capped chicken breast fillet in Hungary. *Heliyon*, 11(1):e41279.

- Martinez-Alier, J. (1995). The environment as a luxury good or “Too poor to be green”? *Économie appliquée*, 48(2):215–230.
- Matiiuk, Y. and Liobikienė, G. (2023). How the Covid-19 pandemic contributed to changes in climate change and environmental concern, resource-saving and waste-sorting behaviour. *Journal of Cleaner Production*, 430:139759.
- Matsumoto, S. (2011). Waste separation at home: Are Japanese municipal curbside recycling policies efficient? *Resources, Conservation and Recycling*, 55(3):325–334.
- Mbiba, B. (2014). Urban solid waste characteristics and household appetite for separation at source in Eastern and Southern Africa. *Habitat International*, 43:152–162.
- McCright, A. M. and Dunlap, R. E. (2011). The politicization of climate change and polarization in the American public’s views of global warming, 2001–2010. *The Sociological Quarterly*, 52(2):155–194.
- McCright, A. M., Dunlap, R. E., and Marquart-Pyatt, S. T. (2015). Political ideology and views about climate change in the European Union. *Environmental Politics*, 25(2):338–358.
- McKinsey (2020). Consumer sentiment and behavior continue to reflect the uncertainty of the COVID-19 crisis. Retrieved from McKinsey & Company.
- Meneses, G. D. and Palacio, A. B. (2005). Recycling behavior. *Environment and Behavior*, 37(6):837–860.
- Metic, J. and Pigosso, D. C. (2022). Research avenues for uncovering the rebound effects of the circular economy: A systematic literature review. *Journal of Cleaner Production*, 368:133133.
- Meyer, A. (2015). Does education increase pro-environmental behavior? Evidence from Europe. *Ecological Economics*, 116:108–121.
- Milios, L. (2017). Advancing to a circular economy: three essential ingredients for a comprehensive policy mix. *Sustainability Science*, 12(3):861–878.

- Mongo, M. (2021). COVID-19 and Cognitive Biases: What Lessons Can Be Learned to Fight Against Global Warming. In *Energy Transition, Climate Change, and COVID-19: Economic Impacts of the Pandemic*, pages 119–133. Springer.
- Morrison, K. R. and Miller, D. T. (2008). Distinguishing between silent and vocal minorities: Not all deviants feel marginal. *Journal of Personality and Social Psychology*, 94(5):871–882.
- Mu, R. and Zhang, L. (2021). Impact of incentives on waste recycling: A case study in urban China. *Waste Management & Research*, 39(2):257–266.
- Mukherjee, S., Bhattacharyya, A., Dar, M. A., Bisht, R., and Parvez, A. (2024). Challenges and perspectives for mitigating the footprints of plastic wastes produced by COVID-19 pandemic. In *Plastic and the COVID-19 Pandemic*, pages 217–227.
- Nadeem, K., Shahzad, S., Hassan, A., Younus, M. U., Gillani, S. A. A., and Farhan, K. (2023). Municipal solid waste generation and its compositional assessment for efficient and sustainable infrastructure planning in an intermediate city of Pakistan. *Environmental Technology*, 44(21):3196–3214.
- Najar, I. N., Sharma, P., Das, R., Mondal, K., Singh, A. K., Tamang, S., Hazra, P., Thakur, N., Bhanwaria, R., Gandhi, S. G., and Kumar, V. (2024). In search of poly-3-hydroxybutyrate (PHB): A comprehensive review unveiling applications and progress in fostering a sustainable bio-circular economy. *Food and Bioproducts Processing*, 148:11–30.
- Namlis, K. and Komilis, D. (2019). Influence of four socioeconomic indices and the impact of economic crisis on solid waste generation in Europe. *Waste Management*, 89:190–200.
- Narayana, T. (2009). Municipal solid waste management in India: From waste disposal to recovery of resources? *Waste Management*, 29(3):1163–1166.
- Naughton, C. (2020). Will the COVID-19 pandemic change waste generation and composition?: The need for more real-time waste management data and systems thinking. *Resources, Conservation and Recycling*, 162:105050.

- Nguyen, T. T., Zhu, D., and Le, N. P. (2015). Factors influencing waste separation intention of residential households in a developing country: Evidence from Hanoi, Vietnam. *Habitat International*, 48:169–176.
- Nielsen (2022). The impact of COVID-19 on consumer behavior: Global insights.
- Norris, C. L., Taylor Jr, S., and Taylor, D. C. (2021). Pivot! How the restaurant industry adapted during COVID-19 restrictions. *International Hospitality Review*, 35(2):132–155.
- Olawade, D. B., Wada, O. Z., Ore, O. T., David-Olawade, A. C., Esan, D. T., Egbewole, B. I., and Ling, J. (2024). Trends of solid waste generation during COVID-19 pandemic: A review. *Waste Management Bulletin*, 1(4):93–103.
- Owusu, V., Adjei-Addo, E., and Sundberg, C. (2013). Do economic incentives affect attitudes to solid waste source separation? Evidence from Ghana. *Resources, Conservation and Recycling*, 78:115–123.
- Oyekale, A. S. (2017). Determinants of households' involvement in waste separation and collection for recycling in South Africa. *Environment, Development and Sustainability*, 20(5):2343–2371.
- Oyekale, A. S. (2018). Determinants of households' involvement in waste separation and collection for recycling in South Africa. *Environment, Development and Sustainability*, 20:2343–2371.
- Pal, A. and Kashyap, A. (2025). Challenging inequality: Rights of the waste workers of Delhi. *Contemporary Justice Review*, pages 1–12.
- Pampel, F. C. (2013). The varied influence of SES on environmental concern. *Social Science Quarterly*, 95(1):57–75.
- Parizeau, K., von Massow, M., and Martin, R. (2015). Household-level dynamics of food waste production and related beliefs, attitudes, and behaviours in Guelph, Ontario. *Waste Management*, 35:207–217.
- Parrot, L., Sotamenou, J., and Dia, B. K. (2009). Municipal solid waste management in Africa: Strategies and livelihoods in Yaoundé, Cameroon. *Waste Management*, 29(2):986–995.

- Patrício Silva, A. L., Prata, J. C., Duarte, A. C., Barcelò, D., and Rocha-Santos, T. (2021). An urgent call to think globally and act locally on landfill disposable plastics under and after COVID-19 pandemic: Pollution prevention and technological (Bio)remediation solutions. *Chemical Engineering Journal*, 426:131201.
- Pearce, D. W. and Atkinson, G. D. (1993). Capital theory and the measurement of sustainable development: An indicator of “weak” sustainability. *Ecological Economics*, 8(2):103–108.
- Ponce, P., Alvarado, R., Ponce, K., Alvarado, R., Granda, D., and Yaguana, K. (2019). Green returns of labor income and human capital: Empirical evidence of the environmental behavior of households in developing countries. *Ecological Economics*, 160:105–113.
- Prentice, C., Quach, S., and Thaichon, P. (2022). Antecedents and consequences of panic buying: The case of COVID-19. *International Journal of Consumer Studies*, 46(1):132–146.
- Pál, V. (2023). Like industrious bees: Paper waste and recycling in communist Hungary, 1950–1990. *Environmental History*, 28(2):335–360.
- Pérez, C., Arroyo, P., Richards, C., and Mourgues, C. (2021). Residential curbside waste collection programs design: A multicriteria and participatory approach using choosing by advantages. *Waste Management*, 119:267–274.
- Rahmandoust, A., Hafezalkotob, A., Rahmani Parchikolaei, B., and Azizi, A. (2023). Government intervention in municipal waste collection with a sustainable approach: a robust bi-level problem. *Environment, Development and Sustainability*, 25(4):3323–3351.
- Ralte, R., Tipandjan, A., Halliday, M. A., Zothanmawia, C., Modi, R., and Nithiya, D. R. (2021). Anxiety and panic buying during COVID-19 pandemic among the Mizo. *International Journal of Community Medicine and Public Health*, 8(3):1445.
- Ranjbari, M., Esfandabadi, Z. S., Zanetti, M. C., Scagnelli, S. D., Siebers, P.-O., Aghbashlo, M., Peng, W., Quatraro, F., and Tabatabaei, M. (2021). Three pillars of sustainability in the wake of COVID-19: A systematic review

- and future research agenda for sustainable development. *Journal of Cleaner Production*, 297:126660.
- Raoufi, K., Tajasob, P., Al-e Hashem, S. M., and Jokar, M. A. (2025). Challenges, opportunities, and future research directions of aggregate production planning: A state-of-the-Art analysis of sustainability, uncertainty, and case studies. *Journal of Cleaner Production*, 489:144686.
- Richter, A., Ng, K. T., Vu, H. L., and Kabir, G. (2021). Identification of behaviour patterns in waste collection and disposal during the first wave of COVID-19 in Regina, Saskatchewan, Canada. *Journal of Environmental Management*, 290:112663.
- Rodríguez-Urrego, D. and Rodríguez-Urrego, L. (2020). Air quality during the COVID-19: PM2.5 analysis in the 50 most polluted capital cities in the world. *Environmental Pollution*, 266:115042.
- Romano, G., Rapposelli, A., and Marrucci, L. (2019). Improving waste production and recycling through zero-waste strategy and privatization: An empirical investigation. *Resources, Conservation and Recycling*, 146:256–263.
- Rootes, C. (2009). Environmental movements, waste and waste infrastructure: An introduction. *Environmental Politics*, 18(6):817–834.
- Ruslinda, Y., Raharjo, S., Aziz, R., Dewilda, Y., and Permadi, R. (2020). Measurement of hazardous solid waste generation and composition from institutional sources in Padang City, Indonesia. In *Proceedings of the 2nd Workshop on Multidisciplinary and Applications (WMA) 2018, 24–25 January 2018, Padang, Indonesia*, pages 24–25.
- Rybova, K. (2019). Do Sociodemographic characteristics in waste management matter? Case study of recyclable generation in the Czech Republic. *Sustainability*, 11(7):2030.
- Rybová, K., Slavík, J., Burcin, B., Soukopová, J., Kučera, T., and Černíková, A. (2018). Socio-demographic determinants of municipal waste generation: Case study of the Czech Republic. *Journal of Material Cycles and Waste Management*, 20(3):1884–1891.

- Sabol, G., Kiš, D., and Kalambura, S. (2022). Analysis of trends and challenges of a worldwide solid waste management with emphasis on COVID-19 pandemic: A review. *Tehnicki vjesnik - Technical Gazette*, 29(5).
- Salkie, F. J., Adamowicz, W. L., and Luckert, M. K. (2001). Household response to the loss of publicly provided waste removal: a Saskatchewan case study. *Resources, Conservation and Recycling*, 33:23–36.
- Saphores, J.-D. M., Nixon, H., Ogunseitán, O. A., and Shapiro, A. A. (2006). Household willingness to recycle electronic waste. *Environment and Behavior*, 38(2):183–208.
- Sarkodie, S. A. and Owusu, P. A. (2021). Impact of COVID-19 pandemic on waste management. *Environment, Development and Sustainability*, 23(5):7951–7960.
- Sarmiento, P., Motta, M., Scott, I. J., Pinheiro, F. L., and De Castro Neto, M. (2022). Impact of COVID-19 lockdown measures on waste production behavior in Lisbon. *Waste Management*, 138:189–198.
- Schultz, W. P., Oskamp, S., and Mainieri, T. (1995). Who recycles and when? A review of personal and situational factors. *Journal of Environmental Psychology*, 15(2):105–121.
- Shaiko, R. G., Dwyre, D., O’Gorman, M., Stonecash, J. M., and Vike, J. (1991). Pre-election political polling and the non-response bias issue. *International Journal of Public Opinion Research*, 3(1):86–99.
- Sharma, H. B., Vanapalli, K. R., Cheela, V. S., Ranjan, V. P., Jaglan, A. K., Dubey, B., Goel, S., and Bhattacharya, J. (2020). Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. *Resources, Conservation and Recycling*, 162:105052.
- Shaw, P. J. and Maynard, S. J. (2008). Waste management best practices and sustainability. *Resources, Conservation and Recycling*, 53(3):143–151.
- Siderius, T. and Poldner, K. (2021). Reconsidering the Circular Economy Rebound Effect. *Journal of Cleaner Production*, 290:125187.

- Sidique, S. F., Joshi, S. V., and Lupi, F. (2010). Factors influencing the rate of recycling: An analysis of Minnesota counties. *Resources, Conservation and Recycling*, 54(4):242–249.
- Singh, N., Parhad, P., Jain, K., and Lal, P. (2024). *Impact of plastic wastes generated during COVID-19 pandemic on population health and well-being*, pages 149–171.
- Singh, N., Parhad, P., Jain, K., and Lal, P. (2025). Impact of Plastic Wastes Generated During COVID-19 Pandemic on Population Health and Well Being. In Anani, O., Shahnawaz, M., Dar, M., and Daochen, Z., editors, *Plastic and the COVID-19 Pandemic: Innovative Solutions to Mitigate Plastic Pollution*, pages 149–171. Springer Nature Switzerland.
- Singh, N., Tang, Y., and Ogunseitan, O. A. (2020). Environmentally sustainable management of used personal protective equipment. *Environmental Science & Technology*, 54(14):8500–8502.
- Soós, G. and Kákai, L. (2011). Hungary: Remarkable successes and costly failures: An evaluation of subnational democracy. In *The Oxford Handbook of Local and Regional Democracy in Europe*, pages 528–551.
- Struk, M. (2017). Distance and incentives matter: The separation of recyclable municipal waste. *Resources, Conservation and Recycling*, 122:155–162.
- Svatosova, V. (2022). Changes in online shopping behavior in the Czech Republic during the COVID-19 crisis. *Journal of Competitiveness*, 14(1):155–175.
- Sánchez, M., López-Mosquera, N., and Lera-López, F. (2015). Improving pro-environmental behaviours in Spain. The role of attitudes and socio-demographic and political factors. *Journal of Environmental Policy and Planning*, 18(1):47–66.
- Talalaj, I. A. and Walery, M. (2015). The effect of gender and age structure on municipal waste generation in Poland. *Waste Management*, 40:3–8.
- Taylor, S. (2000). Policy implications for sustainable waste management. *Environment*, 13(4):271–287.
- Thøgersen, J. (2014). Unsustainable Consumption. *European Psychologist*, 19(2):84–95.

- Timlett, R. and Williams, I. (2008). Public participation and recycling performance in England: A comparison of tools for behaviour change. *Resources, Conservation and Recycling*, 52(4):622–634.
- Tolppanen, S., Kang, J., and Mayoral, O. (2023). Paradigm shift: Changes in willingness to take pro-environmental behavior in the midst of the COVID pandemic among European pre-service teachers. *Environmental Education Research*, 29(9):1259–1275.
- Tomić, T. and Schneider, D. R. (2020). Circular economy in waste management – socio-economic effect of changes in waste management system structure. *Journal of Environmental Management*, 267:110564.
- Tonglet, M., Phillips, P. S., and Read, A. D. (2004). Using the theory of planned behaviour to investigate the determinants of recycling behaviour: A case study from Brixworth, UK. *Resources, Conservation and Recycling*, 41(3):191–214.
- Torgler, B. and García-Valiñas, M. A. (2007). The determinants of individuals' attitudes towards preventing environmental damage. *Ecological Economics*, 63(2-3):536–552.
- Tripathi, A., Tyagi, V. K., Vivekanand, V., Bose, P., and Suthar, S. (2020). Challenges, opportunities and progress in solid waste management during COVID-19 pandemic. *Case Studies in Chemical and Environmental Engineering*, 2:100060.
- Unsworth, K. L. and Fielding, K. S. (2014). It's political: How the salience of one's political identity changes climate change beliefs and policy support. *Global Environmental Change*, 27:131–137.
- van Beukering, P. J. H., Bartelings, H., Linderhof, V. G. M., and Oosterhuis, F. H. (2009). Effectiveness of unit-based pricing of waste in the Netherlands: Applying a general equilibrium model. *Waste Management*, 29:2892–2901.
- Van Fan, Y., Klemeš, J. J., Lee, C. T., and Tan, R. R. (2025). Demographic and socio-economic factors including sustainability related indexes in waste generation and recovery. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 47(1):11100–11113.

- Van Kempen, L., Muradian, R., Sandóval, C., and Castañeda, J.-P. (2009). Too poor to be green consumers? A field experiment on revealed preferences for firewood in rural Guatemala. *Ecological Economics*, 68(7):2160–2167.
- Vanapalli, K. R., Sharma, H. B., Ranjan, V. P., Samal, B., Bhattacharya, J., Dubey, B. K., and Goel, S. (2021). Challenges, opportunities, and innovations for effective plastic waste management during and post COVID-19 pandemic. *Science of The Total Environment*, 750:141514.
- Vargas, I. S., Gomes, F. B., and Castro, S. R. (2023). Reflections on COVID-19 pandemic and waste management in developing countries: A case study in Sao Paulo city, Brazil. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, 42(1):41–50.
- Vassanadumrongdee, S. and Kittipongvises, S. (2018). Factors influencing source separation intention and willingness to pay for improving waste management in Bangkok, Thailand. *Sustainable Environment Research*, 28(2):90–99.
- Vera-Toscano, E., Gómez-Limón, J. A., Moyano, E., and Garrido, F. (2008). Factors determining citizen’s attitudes towards agri-environmental property rights. *Environmental and Resource Economics*, 41(4):541–561.
- Victar, H. C. and Waidyasekara, A. S. (2024). Optimising construction waste management in Sri Lanka through circular economy strategies: A focus on construction and renovation and use and operate stages. *Engineering, Construction and Architectural Management*.
- Videras, J., Owen, A. L., Conover, E., and Wu, S. (2012). The influence of social relationships on pro-environment behaviors. *Journal of Environmental Economics and Management*, 63(1):35–50.
- Vila, M. and Costa, G. (2024). Post-pandemic shifts in pro-environmental attitudes and behaviors in a marine protected area. *Sustainability*, 16(17):7410.
- Vining, J. and Ebreo, A. (1990). What makes a recycler? *Environment and Behavior*, 22(1):55–73.
- Vivanco, D. F., Kemp, R., and van der Voet, E. (2016). How to deal with the rebound effect? A policy-oriented approach. *Energy Policy*, 94:114–125.

- Vorobeva, E. and Wang, S. (2022). Strategies for reducing contamination in recyclable waste. *Journal of Cleaner Production*, 330:129855.
- Wager, S. and Athey, S. (2018). Estimation and inference of heterogeneous treatment effects using random forests. *Journal of the American Statistical Association*, 113(523):1228–1242.
- Wagner, T. P. and Broaddus, N. (2016). The generation and cost of litter resulting from the curbside collection of recycling. *Waste Management*, 50:3–9.
- Wang, H. and Mangmeechai, A. (2021). Understanding the gap between environmental intention and pro-environmental behavior towards the waste sorting and management policy of China. *International Journal of Environmental Research and Public Health*, 18(2):757.
- Welsch, H. and Kühling, J. (2015). Green status seeking and endogenous reference standards. *Environmental Economics and Policy Studies*, 18(4):625–643.
- Werner, C. M. and Makela, E. (1998). Motivations and behaviors that support recycling. *Journal of Environmental Psychology*, 18(4):373–386.
- Wibowo, Y. G., Ramadan, B. S., Miftahadi, M. F., Rachman, I., and Ikhlas, N. (2024). Waste management during COVID-19 pandemic: Could it be time-bomb? *International Journal of Environment and Waste Management*, 34(1):86–104.
- Wiesmeth, H. (2021). The rebound effect and path dependencies. In *Implementing the Circular Economy for Sustainable Development*, pages 141–152.
- Wilson, R. E., Gosling, S. D., and Graham, L. T. (2012). A review of Facebook research in the social sciences. *Perspectives on Psychological Science*, 7(3):203–220.
- Witzke, P. H. and Urfei, G. (2001). Willingness to pay for environmental protection in Germany: Coping with the regional dimension. *Regional Studies*, 35(3):207–214.

- Xiao, L., Zhang, G., Zhu, Y., and Lin, T. (2017). Promoting public participation in household waste management: A survey based method and case study in Xiamen city, China. *Journal of Cleaner Production*, 144:313–322.
- Xie, Y., Brand, J. E., and Jann, B. (2012). Estimating heterogeneous treatment effects with observational data. *Sociological Methodology*, 42(1):314–347.
- Xu, L., Ling, M., Lu, Y., and Shen, M. (2017). Understanding Household Waste Separation Behaviour: Testing the Roles of Moral, Past Experience, and Perceived Policy Effectiveness within the Theory of Planned Behaviour. *Sustainability*, 9(4):625.
- Yoon, J., Yoon, Y., Yun, S. L., and Lee, W. (2021). The current state of management and disposal of wastes related to COVID-19: A review. *Journal of Korean Society of Environmental Engineers*, 43(12):739–746.
- Yu, W., He, L., Lin, X., Freudenreich, T., and Liu, T. (2022). Irrational consumption during the COVID-19 period. *International Journal of Environmental Research and Public Health*, 19(9):5031.
- Yuriev, A., Boiral, O., Francoeur, V., and Paillé, P. (2018). Overcoming the barriers to pro-environmental behaviors in the workplace: A systematic review. *Journal of Cleaner Production*, 182:379–394.
- Zabaleta, I. and Rodic, L. (2015). Recovery of essential nutrients from municipal solid waste – Impact of waste management infrastructure and governance aspects. *Waste Management*, 44:178–187.
- Zerbino, P. (2022). How to manage the circular economy rebound effect: A proposal for contingency-based guidelines. *Journal of Cleaner Production*, 378:134584.
- Zerbino, P. and Aloini, D. (2022). Circular economy rebound: A case-based management guideline. In *EGU General Assembly 2022*.
- Zhang, S., Mu, D., and Liu, P. (2022). Impact of charging and reward-penalty policies on household recycling: A case study in China. *Resources, Conservation and Recycling*, 185:106462.

- Zhao, H., Liu, H., Wei, G., Zhang, N., Qiao, H., Gong, Y., Yu, X., Zhou, J., and Wu, Y. (2022). A review on emergency disposal and management of medical waste during the COVID-19 pandemic in China. *Science of the Total Environment*, 810:152302.
- Zink, T. and Geyer, R. (2017). Circular economy rebound. *Journal of Industrial Ecology*, 21(3):593–602.
- Zorpas, A. A., Voukkali, I., and Loizia, P. (2017). Socio Economy Impact in Relation to Waste Prevention. pages 31–48.
- Zwanka, R. J. and Buff, C. (2021). COVID-19 generation: A conceptual framework of the consumer behavioral shifts to be caused by the COVID-19 pandemic. *Journal of International Consumer Marketing*, 33(1):58–67.

Appendix

Description and documentation of the questionnaire on the circular economy rebound effect (related to Chapter 1)

Table A.1: Facebook Groups and Group Sizes

Facebook Groups	Group size (thousands of persons)
Adok-Veszek Mór	3.1
Algyői hirdető	3.5
Baja és környéke programok, tanfolyamok, szolgáltatások	6
Bajai élet	29
Balassagyarmat & környéke	39
Battonyai Csevegő	4
Békés fórum	17
Békéscsabai csevegő	16
Borbányán beszélnek	3.5
Borsod-Abaúj Zemplén megyei hirdető	5.4
Csanádpalota A Mi Városunk	1.1
Csepeli vagyó	23
Debrecenben Hallottam	152
Dorog élete	8
Dunaújváros	3.1

Continued on next page

Facebook Groups	Group size (thousands of persons)
Dunaújvárosban láttam hallottam találtam új csoportja	11
Edelényi Hírek, Programok	1.8
EGER és környéke INFO	10
Egerben láttam, hallottam	67
Egri ügyek	34
Esztergom	54
Adok-Veszek Mór	3.1
Algyői hirdető	3.5
Baja és környéke programok, tanfolyamok, szolgáltatások	6
Bajai élet	29
Balassagyarmat & környéke	39
Battonyai Csevegő	4
Békés fórum	17
Békéscsabai csevegő	16
Borbányán beszélnek	3.5
Borsod-Abaúj Zemplén megyei hirdető	5.4
Csanádpalota A Mi Városunk	1.1
Csepeli vagyó	23
Debrecenben Hallottam	152
Dorog élete	8
Dunaújváros	3.1
Dunaújvárosban láttam hallottam találtam új csoportja	11
Edelényi Hírek, Programok	1.8
EGER és környéke INFO	10
Egerben láttam, hallottam	67
Egri ügyek	34
Fiatal felnőttek kérdőív kitöltős ilyen-olyan projektekből segítő csoportja	2.5
Gluténmentes élet	4

Continued on next page

Facebook Groups	Group size (thousands of persons)
Gyöngyös Ma	5.1
Győrben és Győr környékén láttam, hallottam	50
Gyulai csevegő	28
Hajdúszoboszlói Hírek, Programok	15
Harkányiak csoportja	8.9
Hatvan	4.9
Helló Maglód	6.6
Hévíz	3.3
HIDAS FALIÚJSÁG	1
Hódmezővásárhelyen élek	4.2
Izsákon hallottam	2.6
Jászberény környékéről mindent ide!	3.5
Jó itt Élni-Gyömrő	33
Kaposvár és Környéke	14
Kaposvári Klebelsberg Kuno középiskolai kollégium (zárt csoport)	1.5
Kazincbarcikaiak a nagyvilágban	8.9
Kecskeméten hallottam	16
Kecskeméten láttam	16
Kérdőív kitöltés, diploma kérdőívek cserebere	11
Kérdőív kitöltők (szakdolgozat, kutatás, segítség)	5.4
Kérdőív kitöltők klubja	9.8
Kérdőív Pont, kérdőív gyűjtemény, kérdőívek és kitöltők	22
Kérdőívek	2.1
Kiskunhalason hallottam	25
Kisújszállási csevegő	7
KISVÁRDÁN HALLOTTAM	25
Kisbéri valóság	3.7

Continued on next page

Facebook Groups	Group size (thousands of persons)
Közösen az új Barcsért	3.4
Lőrinci csoport	1.3
Makón élek	22
Mátészalka és környéke	1.5
Mátészalkán és környékén Hallottam	14
Mezőkövesden Láttam, Hallottam	9.2
Minden ami Nyíregyháza	15
Minden, ami Orosháza!	8
Minden, ami Ócsény	1
Minden,ami Szeged	26
Miskolc és én	82
Miskolcon láttam	86
Mór és környéke	15
Nagykállóban hallottam... (az Igazi)	14
Nagykanizsa és környéke infók, hírek	14
NYÍRBÁTORBAN HALLOTTAM!	10
Nyíregyháza Szabad Hirdető	1
Nyíregyházán hallottam	2.1
Nyírpazonyban hallottam	2.1
Orosháza	2.6
Otthonunk Komárom	6.2
Pécs és környéke minden IS	4.6
Pécsen Hallottam	25
Pilisi infó	7.6
Rákosmente-Budapest, XVII. kerület	33
SARKADI HÍRMONDÓ	8.2
Sárospatakon láttam, hallottam	4.4
Sárszentmihályi Közösség	2.4
Segítsünk egymásnak Hatvaniak	15
Siklósi polgár	6.8
Siófok és környéke	26
Siófoki élet	15

Continued on next page

Facebook Groups	Group size (thousands of persons)
Sopronban hallottam	6.6
Szakdolgozat kérdőív kitöltők	17
Szakdolgozatát kérdőívek S.Oszkárral	11
Szarvasi fórum	14
Szegeden Hallottam	4.8
Szegeden láttam és hallottam	22
Szegedi programok	23
Szekszárd és környéke	11
Szekszárdon hallottam	24
Szentendre Blogol	44
Szentendre hírei	13
Szeretem Székesfehérvárat	62
Szeretem Zagyvaszántót	1.3
Szeretjük Pápát	23
Szigetközben hallottam	1.3
Szolnok és környéke	3.3
Szolnokon Beszélük	16
Szolnokon hallottam	22
Szombathelyen hallottam	16
Tapolca és környéke	8.2
Tatabánya, a Mi városunk	10
Tiszabécskei rendezvény infók-kérdések-válaszok	9.6
TOKAJ, A MI VÁROSUNK	11
Új Miskolcon Láttam	79
Újfehértón hallottam	12
Váchartyánban lakom	2.6
Vácon láttam	5.2
Vajta-közérdekű	51
Vas megye	18
Velencei-tó körül hallottam	17
Veresegyházi Hírmondó	24

Continued on next page

Facebook Groups	Group size (thousands of persons)
Veszprém Infó	6.1
Záhonyiak csoport	3.9
Zalaegerszeg összefog	39
Zamárdiak	14
Kőszeg, a mesebeli kisváros	12
Biharkeresztes, én így szeretlek!	4.6
Őrség és Vendvidék - programok, szállások, szolgáltatások	20
Kenderes és környéke minden ide!	1.4

Table A.2: Survey questions in English

Question Type	Survey Question (English Translation)
Availability	Is selective waste collection available in your place of residence? (a) Separate bins provided at home; (b) Bags are used for collection; (c) Only recycling islands available; (d) Not available at all
Frequency	How often do you separate your waste?
Likert Scale 1	Waste separation contributes to the fight against climate change. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 2	Waste separation can solve waste management problems. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 3	I would like more information on how to separate waste properly. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 4	Curbside waste separation is easy and convenient. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 5	I think that curbside waste separation is a good solution. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 6	The extra bins available at home make it easier to collect waste separately. (1 – Strongly disagree, 5 – Strongly agree)

Continued on next page...

Table A.2 – continued from previous page

Question Type	Survey Question (English Translation)
Likert Scale 7	Curbside waste separation is more convenient than waste separation using large containers on the street. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 8	Curbside waste separation allows me to collect waste separately more efficiently. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 9	Since introducing curbside waste separation, I have been more careful in separating my waste properly. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 10	I am more likely to buy a packaged product if I know that the packaging can be recycled. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 11	If I were to move to a place where waste separation was unavailable, I would be more careful to produce less waste. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 12	Since the availability of waste separation, I am less annoyed when I forget to bring a bag to the store and therefore have to use a disposable plastic bag. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 13	Thanks to curbside waste separation, I don't have to pay as much attention to how much packaging is used in the products I buy. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 14	I feel less responsible for the amount of waste I generate because I collect it selectively. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 15	Thanks to waste separation, it doesn't matter how much waste I produce, because it will be recycled anyway. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 16	Waste separation has a significant positive environmental impact. (1 – Strongly disagree, 5 – Strongly agree)

Continued on next page...

Table A.2 – continued from previous page

Question Type	Survey Question (English Translation)
Likert Scale 17	I am not sure what goes in which recycling bin. (1 – Strongly disagree, 5 – Strongly agree)
Likert Scale 18	I did not separate my waste before curbside collection was introduced. (1 – Strongly disagree, 5 – Strongly agree)
Demographic 1	What is your gender?
Demographic 2	What is your age?
Demographic 3	What is your highest level of education?
Demographic 4	What is the postal code of your place of residence?

List of municipalities included (related to Chapter 2)

Table A.3: Settlements and Their Populations

Settlement	Population	Settlement	Population
Aba	4551	Abádszalók	4180
Abda	3193	Abony	15281
Ács	70586	Adony	3717
Agyagosszergény	887	Ajak	3933
Ajka	30298	Akasztó	3464
Alap	2060	Albertirsa	12528
Algyő	5325	Alsónémedi	5116
Alsózsolca	5955	Anarcs	2007
Apagy	2305	Aparhant	1070
Apátfalva	3149	Arló	3987
Ártánd	539	Ásotthalom	4053
Aszód	6210	Bábolna	3657
Bácsalmás	7126	Bag	3880
Baj	2818	Baja	37455
Bajna	2007	Bakonybél	1245
Bakonycsernye	3149	Bakonynána	1043
Bakonysárkány	973	Baks	2089
Baktalórántháza	3793	Balassagyarmat	16130
Balástya	3560	Balaton	1112
Balatonalmádi	9430	Balatonboglár	6093
Balatonfüred	13778	Balatonfűzfő	4225
Balatonlelle	5086	Balatonrendes	152
Balatonszabadi	2994	Balatonszepezd	440
Balkány	6539	Ballószög	3260
Balmazújváros	18067	Baracs	3537
Baracska	2746	Barcs	11574
Bárna	1076	Bátaszék	6728
Bátonyterenye	13292	Battonya	5992

Continued on next page

Settlement	Population	Settlement	Population
Bátya	2157	Becsehely	2194
Békés	20744	Békéscsaba	62383
Békésszentandrás	3814	Beregdaróc	842
Berekböszörmény	1991	Berettyóújfalu	15439
Berhida	6074	Berzék	1029
Besenyszög	3441	Biatorbágy	12496
Bicske	12098	Biharkeresztes	4168
Bihartorda	1005	Bócsa	1919
Bocskai kert	3135	Bodajk	4157
Bódvaszilas	1116	Boldog	3064
Boldogkőváralja	1031	Bóly	3895
Bonyhád	13871	Bordány	3251
Borsodnádasd	3305	Bököny	3351
Budakalász	10572	Budakeszi	14350
Budaörs	28525	Budapest	1694426
Bugyi	5327	Buják	2159
Bük	3417	Cegléd	37695
Ceglédbercel	4346	Celldömölk	3417
Cibakháza	4388	Cigánd	3239
Csabrendek	3150	Csákvár	5237
Csárdaszállás	486	Csemő	4415
Csenger	5128	Csepreg	3260
Cserszegtomaaj	2914	Csobánka	3202
Csokvaomány	925	Csolnok	3407
Csongrád	17605	Csór	1868
Csorna	2745	Csorvás	5060
Csököly	1122	Csömör	8929
Csurgó	5353	Dabas	17605
Dánszentmiklós	3080	Dány	4407
Debrecen	205122	Decs	4220
Délegyháza	3543	Demecser	4246
Derecske	9080	Deszk	3560
Dévaványa	5268	Devecser	15079

Continued on next page

Settlement	Population	Settlement	Population
Diósd	9072	Diósjenő	2976
Doboz	4217	Domaszék	4883
Dombegyház	2131	Dombóvár	19621
Dombrád	4265	Domoszló	2038
Dorog	12507	Dorogháza	1106
Döbrököz	2048	Dömsöd	6010
Dörgicse	303	Dunabogdány	3243
Dunaföldvár	8910	Dunaharaszti	20782
Dunakeszi	40748	Dunapataj	3373
Dunaszekcső	2086	Dunasziget	1487
Dunaújváros	18967	Dunavarsány	40748
Dunavecse	3881	Dusnok	3161
Ebes	4639	Ecséd	3292
Ecser	3775	Edelény	3239
Eger	54624	Egyek	5504
Elek	4927	Emőd	5252
Encs	6631	Encsencs	2057
Enying	7099	Eperjes	559
Ercsi	7099	Érd	65358
Erdőkertes	7728	Erdőtelek	3411
Erk	947	Érsekcsanád	2951
Érsekvadkert	3741	Esztergom	30129
Etyek	4258	Fadd	4211
Farád	1992	Farmos	3671
Fegyvernek	7016	Fehérgyarmat	4265
Felcsút	1866	Felpéc	888
Felsőlajos	969	Felsőpakony	3410
Felsőtárkány	3551	Felsőzsolca	6631
Fertőd	3348	Fertőszentmiklós	3798
Fony	369	Fonyód	5258
Fót	18993	Földeák	3218
Földes	4203	Fülöp	1766
Füzesabony	3197	Füzesgyarmat	5956

Continued on next page

Settlement	Population	Settlement	Population
Gacsály	927	Gádoros	3974
Galgamácsa	1935	Gárdony	10125
Gávavencsellő	3714	Gomba	2987
Göd	18192	Gödöllő	31931
Gönc	2196	Gönyű	3219
Gyál	23779	Gyékényes	1022
Gyenesdiás	3411	Gyomaendrőd	14331
Győmrő	16353	Gyöngyös	31160
Gyöngyössolymos	3071	Győr	126304
Györköny	1004	Györladamér	1636
Győrszemere	3260	Győrújbarát	3260
Győrzámoly	2480	Gyugy	294
Gyula	31941	Gyulaháza	2067
Hahót	1118	Hajdúböszörmény	31773
Hajdúdorog	31773	Hajdúhadház	13234
Hajdúnánás	17717	Hajdúsámson	13438
Hajdúszoboszló	23801	Hajdúszovát	3173
Hajmáskér	3112	Hajós	3179
Halászi	3081	Harka	1810
Harkány	4160	Harsány	2106
Harta	3632	Hatvan	21456
Hegyeshalom	3557	Héhalom	1006
Hejőbába	1950	Helvécia	4620
Herceghalom	2086	Hercegszántó	2069
Herend	3520	Hernád	4092
Hernádnémeti	3693	Heves	11198
Hévíz	4943	Hévízgyörk	3111
Himesháza	1103	Hobol	980
Hodász	3420	Hódmezővásárhely	46650
Homokszentgyörgy	1167	Hort	3761
Hosszúhetény	3402	Hosszúpályi	5975
Ibrány	7067	Ikrény	1874
Inárcs	4589	Izsák	6063

Continued on next page

Settlement	Population	Settlement	Population
Jánoshalma	6063	Jánossomorja	6093
Jászsalsószyörgy	3676	Jászapáti	4429
Jászárokszállás	9062	Jászberény	27202
Jászfényszaru	5784	Jászfákóhalma	3037
Jászkisér	5669	Jászladány	5837
Jobbágyi	2146	Kaba	6218
Kakucs	2780	Kál	3691
Kállósemjén	3805	Kalocsa	17318
Kamut	1102	Kápolnásnyék	3548
Kaposvár	66478	Kapuvár	6093
Karácsond	3171	Karcag	21091
Kartal	5879	Kaskantyú	1027
Kazincbarcika	30030	Kázmárk	1022
Kecel	17318	Kecskemét	112155
Kemecse	4975	Kenderes	4809
Kengyel	3680	Kerecsend	2375
Kerekegyháza	8858	Kerekharaszt	1023
Keszthely	20229	Kesztölc	2689
Kétegyháza	3927	Kisbér	5652
Kisköre	2949	Kiskőrös	14676
Kiskunfélegyháza	30979	Kiskunhalas	29444
Kiskunlacháza	10305	Kiskunmajsa	11849
Kisnána	1048	Kisoroszi	975
Kistelek	17605	Kisújszállás	11802
Kisvárda	17598	Kiszombor	4086
Kocsord	2988	Kóka	4338
Komádi	5904	Komárom	19735
Komló	26019	Kompolt	2108
Kondoros	5360	Kótaj	4447
Kozármisleny	26019	Kölked	1054
Körmend	11761	Környe	4614
Körösladány	4674	Körösszegapáti	1025
Kőszeg	11503	Kulcs	2821

Continued on next page

Settlement	Population	Settlement	Population
Kunhegyes	8181	Kunmadaras	5819
Kunszentmárton	8181	Kunszentmiklós	11849
Lábatlan	5264	Lajosmizse	11656
Lakitelek	4660	Leányfalu	3385
Lébény	3133	Lengyeltóti	3261
Lenti	8345	Lepsény	3225
Lesenceistvánd	996	Létavértes	5904
Letenye	4287	Levelek	2959
Lőrinci	5863	Mád	2358
Maglód	11759	Makó	24372
Mályi	4124	Mándok	4191
Marcali	11899	Máriapócs	2169
Márkó	1263	Martfű	6832
Martonvásár	5690	Mátészalka	17423
Medgyesegyháza	3830	Mélykút	5456
Mende	4131	Mezőberény	10817
Mezőcsát	6278	Mezőfalva	4846
Mezőhegyes	5712	Mezőkeresztes	4033
Mezőkovácsháza	6327	Mezőkövesd	16866
Mezőladány	1088	Mezőnagymihály	1115
Mezőtúr	17948	Mikepércs	2265
Mindszent	7113	Miskolc	167680
Mogyoród	3606	Mohács	19458
Mohora	974	Monor	18078
Monorierdő	4435	Mór	14653
Mórahalom	6035	Mosonmagyaróvár	32156
Mosonszolnok	1733	Nádudvar	7333
Nagyatád	11899	Nagybajom	3298
Nagycsepely	387	Nagydobos	2169
Nagyecsed	6778	Nagyhalász	5894
Nagyhegyes	2829	Nagyigmánd	2979
Nagykálló	9996	Nagykanizsa	49862
Nagykátá	12786	Nagykovácsi	6373

Continued on next page

Settlement	Population	Settlement	Population
Nagykőrös	24442	Nagylózs	1014
Nagymágocs	3155	Nagymaros	4905
Nagyoroszi	2143	Nagyrábé	2234
Nagyréde	3243	Nagyszénás	5046
Nagytarcsa	3761	Nagyvenyim	4874
Napkor	3800	Nemesgulács	997
Nemesvámos	2725	Noszvaj	1848
Nyáregyháza	3774	Nyékládháza	5146
Nyergesújfalu	5264	Nyírábrány	3974
Nyíracsád	3994	Nyíradony	7937
Nyírbátor	12699	Nyírbogát	3203
Nyírbogdány	3002	Nyíregyháza	119104
Nyírgyulaj	2037	Nyírmada	4983
Nyírmártonfalva	2046	Nyírmeggyes	2730
Nyírpazony	3509	Nyírpilis	862
Nyírtass	2093	Nyírtelek	4983
Nyírvasvári	2008	Nyúl	4150
Ócsa	9290	Onga	4912
Ópályi	3105	Orgovány	3376
Orosháza	29973	Oroszlány	19611
Ostoros	2719	Ózd	37380
Öcsöd	3566	Őrbottyán	7101
Örkény	4942	Öttevény	2968
Pákozd	3160	Paks	19655
Pánd	2029	Pannonhalma	3504
Pápa	31662	Pásztó	13292
Pátroha	3059	Páty	2029
Pécel	15361	Pécs	153195
Pécsvárad	4035	Perkáta	3911
Pétfürdő	4768	Pilis	11638
Pilisborosjenő	3478	Piliscsaba	7141
Pilisvörösvár	14183	Pilisszentiván	4165
Piricse	1880	Pocsj	2751

Continued on next page

Settlement	Population	Settlement	Population
Pócsmegyer	2047	Polgár	8223
Polgárdi	14653	Pomáz	17328
Poroszló	2974	Pusztahencse	1055
Pusztamérges	1183	Pusztaszabolcs	6304
Putnok	7235	Püspökladány	15389
Rábapatonna	2474	Rábapordány	1055
Rácalmás	4491	Ráckeresztúr	3376
Ráckeve	10060	Rajka	175
Rakamaz	4555	Rákóczi falva	5542
Rákócziújfalú	2087	Révfülöp	1199
Rózsaszentmárton	2011	Röszke	3336
Ságújfalú	1058	Sajókaza	3199
Sajólád	3099	Sajószentpéter	12999
Salgótarján	38988	Sándorfalva	6035
Sárbogárd	12743	Sárisáp	2857
Sarkad	29973	Sárosd	3367
Sárospatak	13032	Sárrétudvari	3066
Sárszentmihály	3128	Sárvár	15204
Sásd	3299	Sátoraljaújhely	16173
Seregélyes	4516	Siklós	2873
Simontornya	4213	Siófok	24905
Solt	6781	Soltvadkert	6781
Solymár	10385	Sopron	58214
Sóskút	3176	Sükösd	3858
Sülysáp	10385	Sümege	6454
Szabadbattyán	4644	Szabadszállás	6469
Szada	4620	Szajol	3956
Szalkszentmárton	2894	Szalonna	1047
Szarvas	17063	Szatymaz	4772
Százhalombatta	18981	Szécsény	6075
Szeged	165599	Szeghalom	17063
Szegvár	4579	Székesfehérvár	100288
Szekszárd	34368	Szendrő	4065

Continued on next page

Settlement	Population	Settlement	Population
Szentendre	26619	Szentes	29100
Szentgotthárd	15204	Szentkirály	1993
Szentlőrinc	6824	Szentlőrincváta	1941
Szentmártonkáta	5077	Szentpéterfa	1024
Szerencs	9579	Szigetcsép	2387
Szigethalom	17749	Szigetmonostor	2435
Szigetszentmiklós	35501	Szigetvár	10928
Szikszó	5885	Szirmabesenyő	4438
Szokolya	1765	Szolnok	73760
Szombathely	78462	Sződ	3669
Sződliget	4447	Szuhakálló	1055
Tab	4533	Táborfalva	3457
Tahitótfalu	5640	Taksony	8230
Taktaharkány	3792	Tamási	4213
Tápióbicske	3633	Tápiógyörgye	3629
Tápióság	2751	Tápiószecső	6336
Tápiószele	6279	Tápiószentmárton	5560
Tápiószőlős	3112	Tapolca	16747
Tar	1945	Tarnaszentmiklós	893
Tárnok	9203	Tass	3072
Tát	5510	Tata	23767
Tatabánya	70586	Téglás	6554
Telki	3661	Tét	14414
Tiborszállás	1065	Tiszaalpár	5085
Tiszabездéd	2019	Tiszabura	3100
Tiszacsege	4592	Tiszaeszlár	2708
Tiszaföldvár	11545	Tiszafüred	12010
Tiszagyenda	1052	Tiszakécske	11519
Tiszalök	5629	Tiszalúc	5490
Tiszaszentimre	2290	Tiszaújváros	17919
Tiszavasvári	13473	Tóalmás	3210
Tokaj	4164	Tokod	4143
Tokodaltáró	3112	Tolna	11806

Continued on next page

Settlement	Population	Settlement	Population
Tompa	4267	Tószeg	4437
Tótkomlós	6257	Tököl	10237
Törökbálint	13467	Törökszentmiklós	21965
Törtel	4333	Tura	13467
Túrkeve	21965	Tuzsér	3499
Tyukod	2056	Újfehértó	13352
Újhartyán	2757	Újkenéz	1086
Újkér	998	Újkígyós	5461
Újszász	6506	Úrkút	2129
Üllés	3221	Üllő	11420
Üröm	2603	Vác	35057
Vácduka	1343	Vaja	3711
Vámosgyörk	2025	Vámospércs	5502
Vámosszabadi	1603	Várpalota	21279
Vásárosnamény	3711	Vaskút	3572
Vasvár	4461	Vecsés	20374
Velence	12743	Vép	3450
Veresegyház	16529	Verőce	3663
Verpelét	3929	Vértesszőlős	3128
Veszény	960	Veszprém	57917
Vésztő	7517	Zagyvarékas	3709
Záhony	18963	Zákányszék	2837
Zalabaksa	705	Zalaegerszeg	59272
Zalakaros	2277	Zalacomár	3096
Zalalövő	3029	Zalaszántó	987
Zalaszántó	6816	Zalaszántó	1039
Zirc	7092	Zomba	2174
Zsámbék	5336	Zsombó	3515

List of municipalities included (related to Chapter 3)

Table A.4: List of Settlements

Settlement			
Abony	Apagy	Ártánd	Bakonybél
Balatonrendes	Balatonszepezd	Balmazújváros	Békéscsaba
Bocskaikert	Borsodnádasd	Budaörs	Budapest
Cegléd	Csárdaszállás	Csokvaomány	Debrecen
Derecske	Dörgicse	Dunaföldvár	Dunaharaszti
Eger	Eperjes	Fony	Fülöp
Gödöllő	Gönc	Gyómrő	Győr
Gyugy	Gyula	Hajdúböszörmény	Hajdúnánás
Hajdúszoboszló	Hajós	Harsány	Hatvan
Hernádnémeti	Kalocsa	Kaposvár	Karcag
Kazincbarcika	Kecskemét	Kerecsend	Kisköre
Kiskunfélegyháza	Kiskunhalas	Kisvárd	Komló
Kunhegyes	Lenti	Mezőkövesd	Miskolc
Mohács	Nagybajom	Nagycsepely	Nagydobos
Nagykálló	Nagyrábé	Nyékládháza	Nyíradony
Nyírbogát	Nyíregyháza	Nyírmeggyes	Nyírpilis
Oroszlány	Pécs	Polgár	Poroszló
Pusztamérges	Püspökladány	Révfülöp	Sárospatak
Sárvár	Sátoraljaújhely	Sopron	Szeged
Székesfehérvár	Szerencs	Szigetszentmiklós	Szigetvár
Szombathely	Tapolca	Tarnaszentmiklós	Tatabánya
Tiszaeszlár	Tiszafüred	Tiszaölök	Tiszavasvári
Tokaj	Veresegyház	Veszprém	Zalabaksa
Zalalövő			

Coding scheme and regression results (related to Chapter 4)

Table A.5: Coding scheme for the candidates/parties to be considered left- or right-wing.

Year of Election	Left-wing Parties	Right-wing Parties	Parties	Not Classified
2014	Hungarian Socialist Party (Magyar Szocialista Párt, MSZP), Politics Can Be Different (Lehet Más a Politika, LMP), Together – Party for a New Era and Dialogue for Hungary (Együtt – a Korszakváltók Pártja és Párbeszéd Magyarországért, Együtt–PM), Democratic Coalition (Demokratikus Koalíció, DK)	Fidesz – Hungarian Civic Alliance and Christian Democratic People’s Party (Fidesz – Magyar Polgári Szövetség és Kereszténydemokrata Néppárt, Fidesz–KDNP), The Homeland is Not for Sale (A Haza Nem Eladó Mozgalom Párt), Movement for a Better Hungary (Jobbik Magyarországért Mozgalom, Jobbik)	Allies of Mária Seres (Seres Mária Szövetségesei, SMS), Hungarian Workers’ Party (Magyar Munkáspárt), Prosperity and Freedom (Jólét és Szabadság, JESZ), Community for Social Justice People’s Party (Közösség a Társadalmi Igazságosságért Néppárt), Hungarian Liberal Party (Magyar Liberális Párt, MLP), Hungarian Civic Party of Social Democrats (Szociáldemokraták Magyar Polgári Pártja, Szocdemek)	

Continued on next page

Year of Election	Left-wing Parties	Right-wing Parties	Not Classified
2019	Momentum Movement (Momentum Mozgalom), Politics Can Be Different (Lehet Más a Politika, LMP), Hungarian Socialist Party–Dialogue for Hungary (Magyar Szocialista Párt–Párbeszéd Magyarországért Párt, MSZP–Párbeszéd), Democratic Coalition (Demokratikus Koalíció, DK), Hungarian Workers’ Party (Magyar Munkáspárt)	Fidesz – Hungarian Civic Alliance and Christian Democratic People’s Party (Fidesz – Magyar Polgári Szövetség és Kereszténydemokrata Néppárt, Fidesz–KDNP), Movement for a Better Hungary (Jobbik Magyarországért Mozgalom, Jobbik), Our Homeland Movement (Mi Hazánk Mozgalom)	Hungarian Tailed Dog Party (Magyar Kétfarkú Kutypárt, MKKP), Independent candidates, Hungarian Workers’ Party (Magyar Munkáspárt)

Notes: The ‘Not classified’ column is reserved for parties that had negligible support and did not impact the election outcome. In the municipal election of 2019, two independent candidates in the 20th and 23rd districts were supported by Fidesz–KDNP. As the party did not field any other candidate against them, they were classified as right-wing.

Table A.6: Regression results (dependent variable: vote share of left-wing parties).

Variables	EP elections		Municipal elections	
	Two-year data	One-year data	Two-year data	One-year data
Waste collected separately	-0.280** (0.092)	-0.188. (0.104)	-1.422 (1.167)	-0.505 (1.013)
Waste collected separately × Number of people per dwelling	0.109* (0.051)	0.065 (0.061)	0.365 (0.478)	0.045 (0.522)
Average taxable income	5.000* (2.238)	3.814. (2.045)	-20.261 (44.429)	2.126 (30.240)
Jobseekers registered for more than 180 days	1.805 (1.104)	1.537 (1.043)	-3.795. (1.986)	-7.426 (5.637)
Population aged above 65	-0.551*** (0.138)	-0.483*** (0.129)	-1.812 (2.626)	-0.252 (2.278)
Eligible for public healthcare subsidy	-1.902** (0.611)	-1.395* (0.627)	-3.896 (3.217)	-3.522 (2.145)
Number of people per dwelling	-6.254** (2.424)	-5.703* (2.699)	203.037** (63.057)	140.036* (56.018)
Year 2019	4.672* (1.882)	4.359** (1.642)	35.885 (35.542)	11.920 (21.231)
N	46	46	46	46
Number of districts	23	23	23	23
Adjusted R ²	0.464	0.428	0.789	0.720

Notes: Random effects models for the European Parliamentary elections and fixed effects models for the municipal elections data based on the Hausman test.

Standard errors (in parentheses) are clustered by district.

List of Publications Related to the Dissertation

Bakó, B., Berezvai, Z., Isztin, P., & Ráti, J. (2025). Is it Greener on the Right Side? The Relationship between Political Preferences and Environmental Behavior in Hungary. *East European Politics and Societies*, *forthcoming*.
<https://doi.org/10.1177/08883254251333781>