

ERASMUS UNIVERSITY ROTTERDAM

Erasmus School of Economics

Master Thesis Policy Economics

Bin Business: Evaluating the Effectiveness of EU Directive 2019/904 and the  
Diftar System on Waste Composition

Name student: Tom van den Broeke

Student ID number: 542773

Supervisor: Dr. Josse Delfgaauw

Second assessor: Prof. Dr. Elbert Dijkgraaf

Date final version: 29-07-2024

## **Abstract**

The increasing world population causes the amounts of produced waste to increase tremendously in recent years. As this trend was also visible in the Netherlands, some municipalities introduced a differentiated tariff (diftar) system where households are charged based on the amount of waste they generate. The system gives a monetary incentive to reduce waste and engage in waste sorting. This paper investigates the effects of the diftar system, while also looking at the implementation of Directive 2019/904 of the European Union. The directive aims to reduce the amount of plastic waste that is produced and improve recycling efforts. By using datasets from Statistics Netherlands and COELO, the findings suggest that the implementation of a diftar system reduces the total amount of waste and increases efforts of households to better separate the waste streams at the source. Moreover, the findings of this paper suggest that the implementation of the European directive mainly caused increased awareness among the population on the importance of sorting their waste. This research contributes to understanding the effects of policy interventions on waste composition and provides answers for increasing problems in waste management.

**Keywords:** Diftar, waste management, Directive 2019/904 EU, municipality fixed effects, single-use-plastic

## Acknowledgements

Dear reader,

Before you lies my thesis to conclude the master in Economics and Business with a specialisation in Policy Economics. This thesis looks into the impact of Directive 2019/904 and diftar waste charges on the amount of waste collected within municipalities.

This thesis also marks the end of my time at Erasmus University Rotterdam. After completing my bachelor's in Economics at Erasmus, I stayed here for my master's in Policy Economics. After finishing all courses of the master, I decided to postpone my thesis for one year, as this provided me with some extra time to finish up my bachelor's degree in Law. The process of completing the courses of this master and finishing up my law degree was difficult and demanding. However, it prepared me for this year where both a masters in Company Law and this thesis where to be completed. I can thankfully say that I managed to achieve both of these goals, as I completed the master Company Law and you are reading this thesis. Looking back, my student time in Rotterdam has flown by, but has been very fulfilling to say the least.

I would also like to take this opportunity to thank some people for their help during my studies. First and foremost, I would like to thank prof. Delfgaauw for supervising my thesis. Your critical feedback and supporting ideas helped me a lot in improving this thesis. Moreover, I would like to thank my family for their support in recent years. Doing a double bachelor and master was very time consuming and required me to keep studying a lot. Thankyou for your continued beliefs and support, also when times were tough. Lastly, I would like to thank my girlfriend Eline. Without your motivations and continuing support, completing my studies would have been incredibly more difficult.

Tom van den Broeke

Rotterdam, July 22, 2024

## Table of Contents

1. Introduction.....	5
2. Literature .....	9
2.1. Dutch context.....	9
2.2. Directive 2019/904 EU .....	10
2.3. Effects of diftar .....	11
2.4. Effect of directive 2019/904.....	12
3. Data .....	14
3.1. Description of datasets .....	14
3.1.1. Manipulations of the datasets.....	15
3.2. Descriptive statistics.....	16
3.2.1. Waste charge systems.....	16
3.2.2. Waste composition .....	17
3.3. Missing data .....	19
4. Methodology .....	20
4.1. Ordinary Least Squares Regression .....	20
4.1.1. Assumptions .....	20
4.2. Model.....	22
4.2.1. Original model .....	22
4.2.2. Fixed effects model.....	22
4.3. Robustness Check .....	23
5. Results .....	24
5.1. Main results .....	24
5.2. Robustness checks .....	30
6. Conclusion .....	32
7. Limitations and suggestions .....	34
References .....	35
Appendix.....	38

## 1. Introduction

The use of plastic in our daily life is indispensable. When you quickly look around you at this very moment, chances are high that you could spot multiple products that are produced with plastics. Chances are even bigger that during the day you have seen or used multiple products without even realising that it is (at least partly) made out of plastic. Not only water bottles and plastic bags contain plastic, even the isolation in your house, computer and smartphone are partly built up from plastics (Letcher et al., 2020). In recent years there have been concerns with regard to plastic usage. Although their use is widely spread, it does not only bring benefits. Using plastic materials can cause serious harm to the environment and to our personal health (Cook & Halden, 2020). Research shows that about a fifth of all the plastic that has ever been created has been recycled or burnt (Letcher et al., 2020). However, the biggest amount of plastic waste ends up in the environment. Due to weathering, the plastic waste is fragmented, releasing microplastics (Lee & Jeong, 2023). Not only do we ingest these microplastics through our food or by breathing, microplastics also end up in oceans. This is not only toxic to human beings, but also wildlife is affected (Gómez et al., 2023). Although we would like to recycle more, this is not as easy as it sounds. In short, there is far more plastic waste created than we could manage in terms of recycling (Bharti & Sharma, 2021).

Due to the ever-growing issues with plastics, the European Union decided to step in. By drafting Directive 2019/904, the parliament aimed to reduce the use of (single-use-)plastics. Moreover, they aim to protect both environment and human health (Article 1, Directive 2019/904). The Directive tries to reduce the usage of plastics at the start and the end of the lifecycle (Aristei, 2022). This takes place by trying to limit the production on the one hand and aiming for an increase in recycling on the other. By focusing on the reduction of plastics at the production side, the European directive is one of a kind (Kiessling et al., 2023). The Directive is, according to the authors, a crucial first step but not enough to mitigate the complete plastic pollution problem. It is therefore important to look into other methods and projects that can reduce the amount of plastic.

Apart from the problems and dangers around plastic waste, countries in the European Union are also confronted by the increasing volumes of household waste (Daskalopoulos, Badr & Probert, 1998). One of the main drivers of the increase in waste is the growing size of the population (Minelgaitė & Liobikienė, 2019). Countries therefore face the enormous task to find a way to efficiently cope with the generated waste. Numerous different ideas have been put forward to better manage the waste that is produced. These ideas include both the increased use of recycling (Stoeva & Alriksson, 2017) and policy measures to influence individuals to reduce the amounts of waste they produce (Bartelings & Sterner, 1999).

Some municipalities in the Netherlands introduced a so-called differentiated tariff (diftar) waste charge system as a policy measure. Households located in municipalities that use the diftar system are charged based on the amount of waste they present for collection (De Bruin, Oldenhof & Nijmeijer, 2021). Households are therefore no longer charged based on a fixed rate (e.g. on the size of their household), but they pay a premium for every time they present waste for collection. This system is based on the polluter pays principle (OECD, 2020) as the more waste a household produces, the more of a premium it has to pay for the collection of their waste. This measure therefore tries to incentivise citizens to reduce the amount of waste they produce (Dijkgraaf & Gradius, 2004).

Multiple actions have been taken to improve the collection and overall reduction of waste. Moreover, the diftar system aims to provide individuals with a monetary incentive for waste reduction. The implications of the diftar system might be influenced by the implementation of the European directive. As the directive mainly focusses on plastic, the amount of plastic that is used and collected might significantly deviate from the situation before implementation. This deviation, or the directive itself, might also influence other waste types. In this paper the effects of the directive on the diftar waste charge systems will be investigated. The research question of this thesis is the following:

*“How does Directive 2019/904 impact the effects of the diftar waste charge system on the waste composition in municipalities in the Netherlands?”*

To answer this research question, data from Statistics Netherlands and COELO will be used. Statistics Netherlands provides datasets to the public with information about municipalities. The datasets from Statistics Netherlands that are used for this research are datasets concerning waste in every municipality and a dataset containing general information about individual municipalities. These datasets are gathered from the public database of Statistics Netherlands. COELO, an independent research organisation looking into economical and financial aspects of decentralized government bodies, provided data about the usage of diftar systems by the municipalities in the Netherlands. By combining these information sources, the effectiveness of the diftar system will be estimated and the impact of the EU directive will be investigated. This paper will make use of an OLS regression with and without fixed effects. By including fixed effects, the time-invariant elements will be taken out of the estimated effect.

It has been shown that implementing diftar waste charges lowers the cost for households compared to flat fees for waste collection (De Bruin, Oldenhof & Nijmeijer, 2021). Although this finding is positive for households, it is important for municipalities that there indeed is an effect of the diftar system on the amount of waste that is produced. Bartelings and Sterner (1999) show, based on survey data, that

individuals are often willing to actively reduce the amount of waste and increase recycling when there is proper infrastructure that supports these habits. The reduction of waste will also improve the living environment and health of individuals by lowering the pollution (Cook & Halden, 2020). As the protection of individuals and seas is a main aim of the European Union, diftar and the European directive seem to go hand in hand to protect citizens.

Tam and Tam (2007) showed that a step wise incentive scheme could help reduce the amount of waste produced within an organisation. Another study done in Sweden by Bartelings and Sterner (1999) shows that when a weight-based charge system was introduced to an area, the amounts of waste that households presented for collection were reduced. Allers and Hoeben (2010) found that there is a large reduction of waste in municipalities that use a diftar system that is based on weight instead of volume. This thesis will add to the literature by increasing the timespan of the research compared to research that has already been done. Moreover, due to the introduction of Directive 2019/904, the effects of this directive on the amounts of waste will be investigated.<sup>1</sup>

Due to the incentive that is provided when introducing a diftar system (De Bruin, Oldenhof & Nijmeijer, 2021). Their research creates the expectation that a diftar system is effective to reduce the overall amount of waste in municipalities. Moreover, according to the findings of Allers and Hoeben (2009), it is expected that weight-based diftar charges are more effective in reducing the actual amount of waste in kilograms compared with volume-based charges. This expectation is funded by the idea that volume-based charges can be lowered when the amount of waste is compressed, while this is not possible for weight-based systems. Lastly, the projected effect that Directive 2019/904 has on the waste types is that there is an increase in non-plastic waste types due to a likely substitution away from plastic.

Based on the findings of this paper, the diftar waste charge system is having a reducing effect on household and biodegradable waste. However, there is an increase in plastic and paper waste due to the diftar system. This finding can be explained by better separation of waste streams at the source. Weight-based diftar systems seem to work better for waste types that are mainly heavy in nature. Volume-based systems seem to filter out bulky products from the residual household waste. The impact of Directive 2019/904 is mostly the additional awareness of separating at the source. This creates large reductions in household residual waste, with small increases in other waste types.

This thesis will proceed with a review of the available literature in chapter 2. Within this chapter, the literature on waste will be explored and the exact contents of the diftar system will be discussed. Furthermore, an overview of the aims of Directive 2019/904 will be given. Within chapter 3 the data

---

<sup>1</sup> Due to the unavailability of data with respect to plastic waste in recent years, the connection between the directive and the amount of plastic waste cannot be investigated.

will be described. This chapter covers both information about gathering and forming the datasets, as well as the contents of the data. Chapter 4 describes the estimation strategy and covers the equations that will be estimated. In chapter 5 the results will be presented. Chapters 6 and 7 provide the general conclusions and limitations of the research respectively.

## **2. Literature**

### **2.1. Dutch context**

The collection of waste in the Netherlands goes through pickups at the kerb or dropping off waste at a recycling centre (Goorhuis et al, 2012). In 2011, the authors found that on average the amount of residual waste of a single citizen in the Netherlands was 534 kilograms. Based on the data provided by the authors, the categories of household residuals and biodegradable waste make up the largest portion of the total household waste. Residual waste took up around 226 kilograms while biodegradable waste was around 76 kilograms per individual. Due the large share of total waste, household residuals and biodegradable waste are collected every other week. This is twice as often as other waste categories, like plastic waste and paper and cardboard, which are collected every month (Goorhuis et al, 2012). Specifically for paper and cardboard waste, Dijkgraaf and Gradus (2017) show that most of this waste is picked up locally by schools or sport clubs. Moreover, they note that since 2010 municipalities are required to pick up plastics separately. There is no required way to shape this process. How waste is collected is therefore completely up to the municipalities themselves.

More than half of the municipalities in the Netherlands contracted out the collection of waste to private and public firms (Bel et al, 2010). The other municipalities either collect waste themselves or collaborate with municipalities in close proximity. Based on the research of Dijkgraaf and Gradus (2007), the cost differences between using a public or private firm for the collection of waste is negligible, when these firms won their contract based on competition.

When the waste is collected, there is a multitude of different options that can be chosen to dispose the collected waste. The Netherlands, like many other European countries, have ordered the ways in which they want to deal with the amounts of waste that is produced within their country. The main aim is to reduce the total amount of waste (Dijkgraaf & Vollebergh, 2004). As the total amount of waste cannot be reduced to zero, the Netherlands would primarily want waste to be recycled or reused, before it is placed in an incineration plant or landfill site respectively. Although this ordering is preferred, in reality these goals are not yet met. The method of waste disposal that is used most, based on the amount of waste, in the Netherlands is still incineration (Rijkswaterstaat, 2024).

As the way in which waste is collected can be decided by the municipalities themselves, the municipalities also have the freedom to choose how to charge their citizens for this service. While a lot of municipalities started out by using a fixed waste charge calculated based on the number of residents in the household, more and more municipalities are influenced by the polluter pays principle (De Bruin, Oldenhof & Nijmeijer, 2021; OECD, 2020). This can be seen by an growing amount of municipalities implementing a so called differentiated tariffs (diftar) system for waste charges. The waste charges are

no longer calculated based on the amount of residents in the household under this system, but are calculated based on the amount of waste that the individuals produce. In the Netherlands an increasing number of municipalities implemented a diftar system over recent years. Where 111 municipalities used the diftar system in 2007, this number increased to 175 in 2022. Although the increase might look small at first sight, diftar was used in around 25% of the municipalities in 2007. In 2022 around 51% of the municipalities in the Netherlands used a diftar system. Due to the decreasing number of overall municipalities and the increasing number of municipalities that use the diftar system, a larger number of residents are faced with the diftar system.

Based on Heijen & Elhorst (2018) municipalities choose to implement the system based on the choices of municipalities around them. One of the arguments to copy the systems in neighbouring municipalities is that municipalities might be afraid of waste tourism (Heijen & Elhorst, 2018). Waste tourism is the phenomenon where individuals that live in a “diftar-municipality” drive to another municipality to dump their waste. By transporting their waste to another municipality, the waste charges of residents can lower their own waste charges. Although no evidence is found by Dijkgraaf and Gradus (2004) and Allers and Hoebein (2009) for waste tourism, this is still a concern for a lot of municipalities. Apart from waste tourism the choice for a specific waste charge system is also influenced by the urbanity of a municipality according to Van Beukering et al. (2009). Their findings suggest that problems arise when municipalities that have a high population density. Municipalities with a higher population density are less well equipped to differentiate between the waste of individuals, so allocating the differentiated waste charges to a specific household is difficult.

## **2.2. Directive 2019/904 EU**

In Europe there are growing concerns about the use of single use plastics. Due to plastics being discarded quickly after use, and the great difficulties that come with recycling, plastic products often end up in the environment (Kiessling et al., 2023). Mainly seas and rivers became collection centres for plastic waste (Nikitara et al., 2022). Plastic pollution does not only cause harm to a diverse group of marine life, but it also affects the health of humans (Kehinde et al, 2020). The hazardous effects are mainly caused by the different acids and toxins that are released as a result of heat or weathering. Due to plastic being lightweight, small particles can float and travel enormous distances (Moore et al, 2001). Due to the transboundary nature of the issue, the European Union drafted Directive 2019/904. Similarly to the measures taken in China, the European Union now introduces measures against the use of plastic products (Hurmelinna-Laukkanen et al., 2021).

By introducing Directive 2019/904 the European Union aims to make sure that plastic products do no longer have a negative impact on the environment and health of humans (Article 1, Directive 2019/904). Moreover, it aims to stimulate innovation and the transition to a reuseable economy. The directive states a number of rules that member states need to obey. In an attempt to reduce the number of plastics they prohibit the sale of throw-away plastic products, require marking on products that contain plastics and implement a deposit for small plastic bottles (Directive 2019/904). The overall aim of this directive is to reduce the amount of plastic used in daily life, which would result in less pollution. Moreover, it aims to raise awareness regarding the ways in which waste can be reduced in general.

Looking at similar policy measures, banning single-use-plastic is the best answer to countering plastic pollution (Adam et al., 2020). One problem that legislators encountered when implementing measures regarding the reduction of pollution is that the public had to be involved in setting it up. In the case of Poland, Kasznik and Łapniewska (2023) found that citizens and businesses pointed the finger towards each other when questioned about the cause of waste pollution. This caused the implementation of national measures to be difficult. By setting up measures on an international scale, these problems could be circumvented, which might cause the policy change to have an actual effect.

A new factor that arises with the implementation of the European directive is that producers of goods are responsible for more than just their own production. Producers need to look into the reduction of plastics through the whole value chain (Syberg et al, 2021). The underlying aim of giving more responsibility is that a transition towards a circular economy is attractive. The requirement to keep a close eye on their value chain can also be seen in other European directives, like the Corporate Sustainability Reporting Directive (CSRD, Directive 2022/2464), where firms are accountable for violations of social and environmental norms in their value chain.

### **2.3. Effects of diftar**

As described before, a diftar system is a way to calculate the waste charges an individual has to pay based on the amount of waste that is produced. The main aim of the implementation of such a system is to make individuals aware of their waste production while incentivising them to reduce the amount of waste by charging them (De Bruin, Oldenhof & Nijmeijer, 2021). The incentive behind this implication is that households that are able to reduce their waste are rewarded with a lower charge for waste collection. Van der Werff et al. (2019) found that self-reported and actual household waste decreases when individuals are informed and made aware of the possibilities to reduce the amount of waste they

produce. Moreover, the reduction in waste was still visible after the intervention was over. These findings argue for the effectiveness of implementing a diftar system.

*Hypothesis 1: Diftar waste charge systems reduce the amount of waste in municipalities*

The different types of diftar waste charges can be split into three main categories. These are payment per bag, payment per volume and payment per weight (De Bruin, Oldenhof & Nijmeijer, 2021). The effectiveness of diftar found by Van der Werff et al. (2019) was earlier explained by Allers and Hoebein (2009) as they illustrate that a weight-based diftar system is more effective than the implementation of a volume-based system. The authors argue that volume-based systems are less effective because households might compress their waste. Compressing waste causes a reduction in overall volume, however it does not change the actual amount of waste in kilograms.

*Hypothesis 2: Weight-based diftar charges cause a larger reduction in waste compared to volume-based charges*

According to the analysis of Van Beukering et al. (2009), a further implementation of the diftar system in the Netherlands could be cost beneficial for both citizens and municipalities alike. When looking at plastic waste specifically, Groot et al. (2014) found that recycling plastic by households themselves, compared to separation by waste facilities, was more cost efficient for society. This not only has to do with a reduction in cost for collection at the curb, but also due to the reduction in greenhouse gas emissions. The awareness and incentives of the diftar system therefore suggest that there is a reduction in cost expressed in monetary value and in social (environmental) value.

#### **2.4. Effect of directive 2019/904**

Specifically, the Dutch context is of interest with respect to the European directive. As a multitude of municipalities in the Netherlands is already actively trying to reduce the amount of waste by the implementation of a diftar waste charge system, the directive could add to the effectiveness. Banning specific plastic packaging, combined with separating waste streams, causes an increase in recycling rates in Germany (Schmidt and Laner, 2021). These findings are important towards reaching a world with less waste pollution.

Apart from the aim to reduce plastic waste, the directive also requires member states to implement measures that raise awareness and incentivises the residents to act in a responsible way when it comes

to waste. The requirement of raising awareness gives an opportunity to member states to educate the citizens (Nikitara et al., 2022). Moreover, it creates opportunities for innovation in businesses (Hurmelinna-Laukkanen et al., 2021). Apart from that, publicity and education seem to help with the self-reported willingness to act with regard to reducing the amount of produced waste in the context of Greece (Charitou et al., 2021).

However, by making use of the diftar-system in different municipalities, it is important to investigate if the addition of policy interventions do not create too much strain on the population of these specific municipalities. Moreover, it is important to check if the additional measures create a substitution effect, where plastic is substituted for other types of waste as was suggested by Gómez and Escobar (2022).

Although substituting plastics might have a positive effect on plastic pollution, there are also downsides. When substituting plastic for alternative materials in sectors where the use of plastic is key, the alternatives often produce a lot more greenhouse gasses (Meng et al. 2024). These alternatives therefore impact the environment in a negative way. When reducing the amount of plastic in daily life, substitutes need to be found. For example, by reducing the usage of plastic bags, individuals will switch towards biodegradable bags (Gómez and Escobar, 2022). The reduction of plastics could therefore cause an increase in other waste types.

According to the findings of Nuojua, Pahl and Thompson (2024) individuals feel like it is important to make sure that plastic waste is recycled. This was not the case for other waste types like glass. The authors moreover find that different types of packaging material cause different levels of urgency when looking at recycling waste types. Due to the message that is send by the directive, that plastic waste is harmful for the environment, this might cause individuals to substitute their plastic usage towards other waste streams. As individuals are separating their waste in diftar municipalities, it is likely that residents of these municipalities are more likely to see an increase in non-plastic waste types.

*Hypothesis 3: The implementation of Directive 2019/904 leads to larger increases in non-plastic waste types in diftar municipalities compared with municipalities that do not use the diftar system.*

### **3. Data**

#### **3.1. Description of datasets**

To investigate the effect of using the diftar waste charge system by municipalities on the amount of waste they collect, information is needed for both the amount of waste of a municipality and the type of diftar system that is used in the municipality. Statistics Netherlands (hereafter: CBS) investigates and collects data on various topics in the Netherlands. Depending on the topics, they create datasets on individual, municipal or province level. These datasets are stored in Statline, the database of CBS. The stored datasets are freely available to the public. For this paper I will use datasets 83452NED and 70072NED of CBS Statline. In dataset 83452NED information is given about the amount of waste that is collected per resident for every municipality. Dataset 70072NED contains some control variables about municipalities in the Netherlands. Some examples of variables that are included in this dataset are the population density and urbanity in a certain municipality. Moreover, the dataset also consists of information about the background of individuals in the municipality and the average value of housing. This data is collected over a time period from 2001 until and including 2022. Within this time period the Netherlands consisted of around 460 to 340 municipalities. On average, around 6 municipalities disappeared every year. How I handle the reduction of municipalities will be discussed in chapter 3.1.1.

There are many different ways in which residents could be charged for their waste to be collected. As mentioned before, the way in which waste is collected in the Netherlands can be done through a system called “diftar”. This system essentially charges the residents based on the amount of waste they produce. This could be measured by the number of bags they present for collection, the total weight of their waste or the number of times their garbage cans are emptied. In all these instances, the diftar system is used. However, apart from diftar systems, there are also municipalities that calculate the waste charges based on a standardised amount, size of the household or the size of the garbage container. These methods are not classified as diftar waste charge methods as they are not based on the amount of waste that residents present for collection. Since municipalities are free in their choice with respect to which type of waste charge they would like to use, it is important to know which charge type is used in every municipality. COELO provided me with data regarding the type of waste charges that is used in every municipality for the years 1998 to 2024. COELO looks at economical and financial aspects of decentralized government bodies. As an independent research organisation, they look at different economical questions specifically focused on province or municipality level.

The three datasets mentioned above all consisted of information about the same municipalities in the same years. Therefore, it was possible to combine them. For the complete dataset only data for the

time period of 2001 until and including 2022 will be used as for this period information is possessed about both the amount of waste that is collected as well as the type of waste charge system that is used in the municipalities.

### **3.1.1. Manipulations of the datasets**

The entire dataset is covering a timespan from 2001 to 2022. Within this time there were multiple changes with respect to the restructuring of municipalities in the Netherlands. There were three cases that are important to mention with regard to the restructuring of municipalities.

First, there were a few cases where municipalities split up to be separate. For these cases there was no problem in merging the datasets. The information on the type of waste charge that was used was not overlapping with any other observations, as new municipalities were created. For these separate municipalities the amount of waste that was collected was also separated, so I did not need to alter any information with regard to this restructuring. Municipalities splitting up only caused empty observations for the original municipality in later years. These observations were deleted as the municipality did not exist anymore in these years.

The second restructuring possibility was that a larger municipality swallowed up one or more smaller municipalities. In this instance the name of the largest municipality remains. Municipalities that were swallowed up did not always have similar waste charge systems in place as the municipality that they joined. This caused multiple different types of waste charge systems to be allocated to the new municipality for a few years. This issue prohibited the matching process, as one municipality can only have one type of waste charge system. Therefore, I had to alter this specific information. I have assigned the waste charge system that was used in the largest municipality, by number of residents, to be used in the “new” municipality for the years that there were different systems allocated. The reason behind this choice was that the system that was used in the largest municipality would have impacted the amount of waste the most within the new municipality.

The last restructuring option was that multiple smaller municipalities were merged to a completely new municipality with a new name. For these new municipalities I have assigned the waste charge system that was used by the municipality that had the most residents before they merged. This change was necessary as the waste charge system that was used in the newly merged municipality was reported multiple times in the year where municipalities merged. This prohibited the matching process of datasets and required altering.

## 3.2. Descriptive statistics

### 3.2.1. Waste charge systems

Within the dataset a multitude of different waste charge systems are used. In total there are ten different types of systems that municipalities can use.<sup>2</sup> These ten can be subdivided into non-diftar and diftar charge systems. Waste charge systems 1, 2 and 3 are considered to be non-diftar. These systems respectively entail a fixed amount per household, a fixed amount based on the size of the household and the volume of the garbagecan. Waste charge systems 4 until 9 are considered to be a diftar waste charge system. The fourth charge system is based on the number of garbagecans that are emptied. The fifth, sixth and seventh are based on the number of bags that are collected, the number of bags and size of the household and the number of bags in combination with how often the waste is collected respectively. Charge systems 8 and 9 are based on the weight of the waste that is offered for pickup, where system 9 also looks at the number of pickups. The tenth category is the residual category for methods that are not considered to be falling into the other methods.

**Table 1: Descriptive statistics by diftar**

	2007			2012			2017			2022		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
<b>Non-diftar</b>												
Municipality population	332	40.483	65.767	297	45.040	72.775	231	52.818	85.048	169	65.107	101.329
Population density	332	876	1.023	297	925	1.084	231	1.032	1174	169	1.242	1.304
Household size	332	2,39	0,20	297	2,33	0,20	231	2,26	0,19	169	2,21	0,20
Woz-value (x100.000)	332	235	63	297	252	66	231	230	67	169	335	102
Dutch background	332	86,95%	7,84%	297	86,05%	8,18%	231	83,63%	9,03%	169	79,90%	10,60%
<b>Diftar</b>												
Municipality population	111	26.284	23.987	118	28.418	24.799	157	31.087	26.220	175	37.524	28.094
Population density	111	464	466	118	494	491	157	509	522	175	569	612
Household size	111	2,49	0,19	118	2,37	0,17	157	2,31	0,16	175	2,26	0,15
Woz-value (x100.000)	111	247	44	118	249	52	157	223	41	175	313	57
Dutch background	111	89,94%	4,79%	118	88,30%	6,53%	157	87,50%	6,41%	175	85,37%	6,66%

Note: Waste charge systems 1,2 and 3 are considered non-diftar and the charges are calculated based on fixed charges, charges based on household size and the volume of the garbagecan respectively. The other systems are considered diftar systems and calculate the charge based on how often a garbagecan are emptied (4), number of bags collected (5), number of bags and household size (6), the total weight (8) and weight combined with number of pickups (9).

<sup>2</sup> For the timeframe of 2001 until 2006 both the municipality of Eemsmund and Leiden did not levy a waste charge. Levying no charge is not considered to be one of the ten different types of systems.

When looking more specifically at the differences between municipalities that use diftar compared to non-diftar waste charge systems in Table 1, it is noticeable that there is a shift towards the use of diftar systems. The descriptive statistics are given for the years 2007, 2012, 2017 and 2022. These years provide a step-by-step overview of changes that occurred between the diftar system. The means and standard deviations are calculated based on the information of all the municipalities that makes use of the specific system in a specific year. Based on these descriptives it is clear that larger municipalities in size and in density more often make use of non-diftar waste charges. The average values for household size and Woz-value do not differ by much. However, there is a slightly higher number of individuals that have parents that both have the Dutch nationality in municipalities that use a diftar system.

Table A1 contains a more extensive overview of descriptive statistics per waste charge systems. The table shows that most municipalities either use waste charge system 2 or 4. Over time more municipalities start making use of the diftar charge systems. Based on the mean of municipality population, larger municipalities tend to prefer charge systems 1, 2 and 3. Although municipalities with larger amounts of residents tend to use these systems, also small municipalities are using these waste charges. This is shown by the large standard deviations. Similarly to the size of the population in the municipality, the population density seems to be higher in municipalities that use the first three charge systems. Household size does not seem to be very different between the waste charge systems. However, the Woz-value, which is the value of houses, is a little higher in municipalities where charge systems 1, 2 and 3 are used. However, the spread in prices is also larger compared to the other charge systems.

Based on the information shown in Table 1 and Table A1, I conclude that the municipalities that use a non-diftar waste charge system are generally more urban. This finding is similar to the conclusions of De Bruin, Oldenhof & Nijmeijer (2021) and Van Beukering et al. (2009).

### **3.2.2. Waste composition**

There is a multitude of different types of waste that are included in the dataset. For this paper I will make use of the information about residual household waste, plastic waste, biodegradable waste and paper and cardboard. These four types of waste are separated within households before they are collected. Households can therefore greatly influence the amount of waste that is produced.

Based on Table 2, on average, the amount of waste per resident in municipalities is reducing. This is not only the case in non-diftar municipalities, but the same trend can be found in municipalities that use the diftar system. Although the reduction in both systems is similar in absolute amounts per resident, the biggest relative reduction is taking place in non-diftar municipalities. This could simply be

the case because there is more waste in the non-diftar municipalities, as the trends in absolute values are similar.

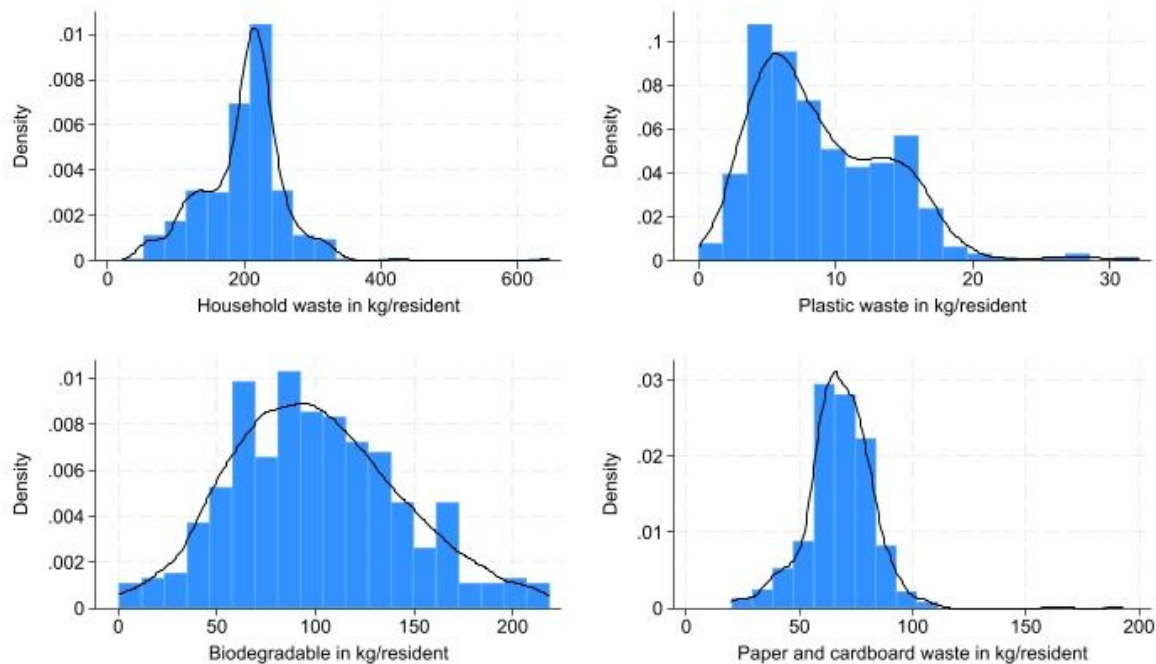
When taking a closer look at the amounts of plastic waste, there is an increasing trend. In both diftar and non-diftar municipalities the amount of plastic waste per resident seems to increase over time. As found in chapter 2.2, societies become more and more dependent on plastic. Unfortunately, due to a lack of information about plastic waste in municipalities after 2018, these amounts are not included in the table or analysis.

**Table 2: Descriptive statistics by diftar and waste type**

	2007			2012			2017			2022		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
<b>Non-diftar</b>												
Household residual	318	244,80	40,55	284	226,48	43,98	219	198,50	55,86	154	175,25	68,63
Plastic	50	1,71	4,19	243	6,46	2,79	28	7,30	4,72	X	X	X
Biodegradable	315	114,07	41,40	280	109,18	39,37	215	109,81	45,24	152	100,49	44,96
Paper and cardboard	306	75,53	20,47	281	65,14	17,21	218	57,362	17,89	150	47,54	19,57
<b>Diftar</b>												
Household residual	107	149,08	43,13	116	131,80	42,97	152	100,89	37,77	163	86,80	33,89
Plastic	26	4,35	5,57	110	14,60	4,00	10	18,48	11,23	X	X	X
Biodegradable	107	76,40	48,16	117	80,09	45,74	152	117,71	47,89	164	121,95	37,70
Paper and cardboard	105	86,15	14,35	117	74,95	10,82	151	65,15	8,67	161	52,40	8,15

Note: The number of municipalities that reported their waste per type is given by N. The means and standard deviations are given in kilograms per resident. Due to a low number of municipalities reporting data for plastic waste onwards from 2018, these observations are not included in the table and in the analysis.

It is noticeable that the standard deviations tend to be large. This shows that there is a large spread in the amounts of waste produced between municipalities. The spread seems to be the lowest in the category of paper and cardboard. On the other hand, the spread is the largest in the category of biodegradable waste. The distribution of the amount of waste by municipalities per waste category for the year 2012 are shown in Figure 1.



**Figure 1: Municipality density per waste category and amount of waste in 2012**

Within the appendix Figure A1 and Figure A2 show the spread per waste category for the year 2012 per diftar system. The comparison shows that the differences in the amount of waste produced between diftar municipalities is higher than in non-diftar municipalities.

### 3.3. Missing data

The complete dataset consists of data for every municipality. Some municipalities were combined with other municipalities or disappeared altogether. For these municipalities, there are still observations without any records in the period after the municipality ceased to exist. These observations will not be included in the analysis. Moreover, there is only a limited number of control variables per municipality available. Most of these variables are shown above in the descriptive statistics tables.

The variable for the urbanity in a municipality not only has missing data, but it also underwent changes in the way it was measured since 2014. Due to this change, the data measured before and after is significantly different. As a result, this information is no longer comparable and can therefore not be reliably used in the analysis.

In more recent years, a lot of municipalities did not report the amounts of plastic waste that was produced. Therefore, the analysis will not contain conclusions about plastics in the later years.

## **4. Methodology**

### **4.1. Ordinary Least Squares Regression**

In this paper I will use an OLS-regression to investigate the effects of the charge on waste collection for the amount of waste that needs to be collected within a specific municipality. The OLS-regression will estimate the effect by creating a best linear fit through the datapoints, based on minimizing the squared distance from each datapoint to the regression line (Burton, 2021).

#### **4.1.1. Assumptions**

There are multiple assumptions that need to hold to be able to causally interpret the effects that are estimated through OLS-regression. The three main assumptions are the zero-conditional mean (ZCM) assumption, the assumption that the observations are independent and identically distributed (i.i.d.) and that large outliers are unlikely to exist. Hereafter I will dive into each assumption and explain if this assumption will hold, and if not, how I will try to deal with this problem.

##### **Assumption 1: Zero-Conditional Mean**

The zero-conditional mean assumption entails that the error term is not correlated with the treatment variable. This assumption translates to this paper as follows. It is not allowed to have a variable, that is not incorporated in the model, which influences both the choice of waste charge system that is used in a municipality and the amount of waste produced by a municipality. Moreover, to interpret the estimations of the OLS regression causally, it is required that municipalities in the Netherlands that use a diftar system and municipalities that do not use the system are similar. Ideally, the choice for a diftar system must be random. If both of these requirements hold, the difference in outcomes is only due to the implementation of the diftar system.

As described before in chapter 2.1, the choice for the use of a specific waste charge system is influenced by the surrounding municipalities (Heijnen & Elhorst, 2018). Moreover, this choice is based on how urban a municipality is (Van Beukering et al., 2009). Urbanisation causes problems with implementing diftar waste charge systems, so municipalities refrain from implementation. It is therefore necessary to control for the level of urbanisation in a municipality. Since the variable for urbanisation is flawed,<sup>3</sup> the population density will be used as a proxy. This variable measures the amount of people that live within a square kilometre instead of a variable for urbanisation that measures the number of addresses within a square kilometre within the municipality.

---

<sup>3</sup> See chapter 3.3.

Based on the descriptive statistics, there is a difference between diftar and non-diftar municipalities with respect to urbanisation. For the other variables in the dataset, no large differences are visible. However, this does not mean that municipalities are alike. It is likely that there are unobserved variables that differ between diftar and non-diftar municipalities which would cause the estimated effects to be biased. An example of an underlying difference is the population demographic. In municipalities that are more rural, it is likely that there is a larger share of elderly citizens compared to urban municipalities. When age influences how adequately individuals follow the rules with respect to waste disposal, this could cause an underlying difference between diftar and non-diftar municipalities which would lead to a biased estimator of the diftar coefficient.

### **Assumption 2: Independent and identically distributed assumption**

The assumption that observations should be independent and identically distributed means that observations may not be influenced by other observations within the dataset. In the dataset as described in chapter 3.1 of this paper, municipalities are included with data for multiple years. It is very unlikely that the amount of waste per resident fluctuates largely from year to year. This means that the observations are likely dependent on the observations of previous years for the same municipality. Due to the panel structure of the dataset, it is therefore important to include municipality fixed effects into the regression. This is possible as the choice of charge system is made separately for every municipality. By including municipality fixed effects, the structural or time-invariant characteristics of the municipalities will be filtered out of the causal effect of waste charge system on the amount of waste. The use of municipality fixed effects uses within-municipality variation. By implementing fixed effects into the regression, the relationship between the diftar system and the amount of waste is estimated only for municipalities that implemented the diftar system. To overcome the problems with respect to the second assumption, in addition to a regular OLS model, I will include an OLS model with municipality fixed effects.

### **Assumption 3: Large outliers are unlikely**

The third assumption of the OLS-regression requires that large outliers in the dataset are unlikely. When looking into the data for the amount of waste municipalities are collecting, there are no large outliers present in the dataset that will drive the results. Moreover, it will also not be likely that the data will consist of any mistakes which have outliers as a result. This is the case because the data, that is collected by CBS, is carefully checked within that organisation.

## 4.2. Model

### 4.2.1. Original model

To estimate the effect of the waste charge system on the amount of waste that is produced, the following regression equation will be used.

$$Y_{mtw} = \alpha + \beta_1 X_{D\_mt} + \gamma_i X_t + \vartheta X_{dtw} + \varepsilon_{dmt} \quad (1)$$
$$\gamma_i = \langle \gamma_1, \gamma_2, \dots, \gamma_{22} \rangle, \delta_i = \langle \delta_1, \delta_2, \dots, \delta_{22} \rangle$$

$Y_{mtw}$  shows the amount of waste in a specific municipality (m) per resident of the municipality, at a certain time (t) ordered by the type of waste (w).  $\alpha$  is the constant.  $\beta_1$  captures the effect of utilising a diftar waste charge system ( $X_{D\_mt}$ ). Where the dummy ( $X_{D\_mt}$ ) equals 1 if a diftar system is used or 0 when this is not the case.  $\gamma$  captures the year effects of the different years in the dataset ( $X_T$ ).  $X_{dtw}$  consist of the control variable of population density.  $\varepsilon_{dmt}$  is the error term.

After running the base model shown before as equation (1). A similar model interchanging the diftar charge system ( $X_{D\_mt}$ ), for the different waste systems that a municipality can choose from will be estimated.

To investigate if there is an effect of the implementation of Directive 2019/904 of the European Union, a dummy variable  $X_{EU}$  will be added, that equals 1 if the directive is implemented and 0 otherwise. This results in equation (2).  $\rho_1$  captures the interaction between the European directive and the existence of diftar.

$$Y_{dmt} = \alpha + \beta_1 X_{D\_mt} + \gamma_i X_t + \rho_1 (X_{EU} * X_{D\_mt}) + \vartheta X_{dmt} + \varepsilon_{dmt} \quad (2)$$
$$\gamma_i = \langle \gamma_1, \gamma_2, \dots, \gamma_{22} \rangle, \delta_i = \langle \delta_1, \delta_2, \dots, \delta_{22} \rangle$$

### 4.2.2. Fixed effects model

After running the base model equations, municipality fixed effects ( $\varphi$ ) will be implemented into the equation. By including the fixed effects into the OLS-equation, the observations for the same municipality over time are no longer influenced by time-invariant variables, as they are captured by the fixed effects term. This causes equation (1) to change to the following model.

$$Y_{mtw} = \alpha + \beta_1 X_{D\_mt} + \gamma_i X_t + \delta_i (X_{D\_mt} * X_t) + \varphi_{mtw} + \vartheta X_{dmt} + \varepsilon_{dmt} \quad (3)$$
$$\gamma_i = \langle \gamma_1, \gamma_2, \dots, \gamma_{22} \rangle, \delta_i = \langle \delta_1, \delta_2, \dots, \delta_{22} \rangle$$

Similarly as before, also a version of this equation will be estimated interchanging the diftar system for a categorical variable that consists of the waste charge options a municipality can choose from.

Specifically for the amount of plastic waste that is gathered within the municipality, I will also add the dummy variable for the EU directive. This results in equation (4).

$$Y_{dmt} = \alpha + \beta_1 X_{D\_mt} + \boldsymbol{\gamma}_i X_t + \rho_1 (X_{EU} * X_{D\_mt}) + \varphi_{mtw} + \vartheta X_{dmt} + \varepsilon_{dmt} \quad (4)$$

$$\boldsymbol{\gamma}_i = \langle \gamma_1, \gamma_2, \dots, \gamma_{22} \rangle, \boldsymbol{\delta}_i = \langle \delta_1, \delta_2, \dots, \delta_{22} \rangle$$

### 4.3. Robustness Check

As described earlier in chapter 3.1.1, within the dataset multiple municipalities had a restructuring of their borders. Due to the restructuring some of the new municipalities were reported to have multiple charge systems in place within one municipality, which is not possible. Due to the manual change, based on the number of residents from the original municipalities, the actual waste charge system might not be similar as the system has been assigned. Therefore, to make sure these manual changes are not driving the results, the same equations as before will be estimated without the municipalities that required altering.

## 5. Results

### 5.1. Main results

The associated influence on waste when implementing a diftar waste charge system is shown in Table 3. Column 1 through 4 show the coefficients for the different types of waste without using municipality fixed effects. These columns show a clear division in the effect of the diftar system. When looking at household residuals and biodegradable waste, the implementation of a diftar system is associated with a reduction of 93 and 26 kilograms per citizen per year, respectively. This is about a two standard deviation reduction for household waste and half a standard deviation for biodegradable waste. However, the diftar system is associated with a small increase in the amount of plastic and paper and cardboard waste in kilograms per citizen per year. This result can be explained by the fact that implementing a diftar system encourages separation at the source. Due to the monetary incentive, individuals will first and foremost try to reduce the total amount of waste. Moreover, as found by Dijkgraaf and Gradus (2017), paper and cardboard are often collected by schools and sport clubs. Therefore, individuals are incentivised to separate paper and cardboard from their residual waste, as they do not have to pay for the collection of paper and cardboard by schools and sport clubs. Essentially, citizens could lower their waste charges by separating waste properly.

When introducing municipality fixed effects in Columns 5 through 8, the coefficients of the diftar variable reduces for household residual and biodegradable waste. The reductions associated with the implementation of a diftar system seems to be around 67 and 8 kilograms on a yearly basis respectively. This is a reduction of one and a half standard deviation for residual waste and less than a quarter of a standard deviation for biodegradable waste. The categories of plastic and paper and cardboard are only changing by half a kilogram of waste on a yearly basis. This shows that the findings, in terms of sign, are robust and indicate a positive effect of the diftar waste charge system on waste separation and overall amount of waste. These findings therefore suggest that hypothesis 1, the overall amount of waste in a municipality will reduce due to a diftar system being in place, holds.

To investigate hypothesis 2, that weight based diftar systems are more effective to reduce the amount of waste compared with volume based diftar systems, the diftar dummy of Table 3 is interchanged with a categorical variable that indicates the type of waste charge that is used. The results of this regression in Table 4. In this Table, waste charge systems 5 and 6 indicate volume-based methods, where charge types 8 and 9 indicate weight-based methods. The coefficients given for every waste charge are estimated compared with reference category “zero”, where no waste charge is levied.

**Table 3: Regression effect diftar**

	(1) Household residual	(2) Plastic	(3) Biodegradable	(4) Paper/Cardboard	(5) Household residual	(6) Plastic	(7) Biodegradable	(8) Paper/Cardboard
Diftar	-93.218*** (1.071)	6.448*** (0.175)	-26.084*** (1.057)	6.198*** (0.325)	-66.567*** (3.174)	6.071*** (0.882)	-7.533** (3.194)	5.575*** (0.843)
Population density	0.010*** (0.001)	-0.001*** (0.000)	-0.025*** (0.000)	-0.007*** (0.000)	-0.004 (0.005)	-0.003 (0.002)	-0.012* (0.007)	0.002 (0.002)
Constant	235.097*** (2.490)	-0.002 (0.419)	135.103*** (1.581)	78.426*** (0.687)	241.305*** (4.317)	1.569 (1.727)	119.173*** (5.158)	71.184*** (1.373)
Observations	8,779	3,113	8,713	8,652	8,779	3,113	8,713	8,652
Number of municipalities	560	447	559	558	560	447	559	558
Year dummies	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	NO	NO	NO	NO	YES	YES	YES	YES

Note: Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Fixed effects are on municipality level.

Columns 1 through 4 of Table 4 indicate that volume-based charges are associated with having a larger reduction in household residual waste compared with weight-based methods, when both of these methods are compared with the reference category. Where the associated effect for plastics is not very different between the volume based and the weight-based categories (both around a reduction of 6 kilograms), there seems to be a greater difference for biodegradable waste. Biodegradable waste tends to reduce far more when a weight-based system is used compared to a volume-based system, around 110 to 115 kilograms yearly. This is around two standard deviations from the mean. On the contrary, household residual waste seems to reduce more when volume-based charges are implemented, by around 30 to 50 kilograms yearly.

The reason for this finding is that biodegradable waste is likely to be more heavy than residual household waste. This causes the charge system based on weight to be more effective, since a direct reduction in the amount of waste has a direct effect on reducing the total charges. For household waste this is different as it is composed of a multitude of different types of waste. The incentive that is given by a volume-based charge might be more effective for reducing household residual waste as it incentivises households to separate large, bulky products from their residual waste. The downside of this method is that theoretically, smaller products can be compressed to limit the waste charges as found by Allers and Hoeben (2009). Based on the findings, larger and bulkier products are separated out of the household waste when a volume-based charge system is used.

When implementing municipality fixed effects in Columns 5 through 8, the larger difference in effectiveness between the two methods seem to fade for household residual waste. However, there is still a difference in sign for biodegradable waste. The results therefore seem to be consistent in terms of sign, however, there is a change in magnitude. This change arises due to the differences between municipalities, as time-invariant differences between municipalities are filtered out of the model after implementation of fixed effects.

**Table 4: Regression effect charge system**

	(1) Household residual	(2) Plastic	(3) Biodegradable	(4) Paper/Cardboard	(5) Household residual	(6) Plastic	(7) Biodegradable	(8) Paper/Cardboard
Charge system 1	-70.334*** (23.736)		-41.428*** (3.111)	-14.539*** (1.954)	-23.874 (20.221)		20.998 (21.090)	-3.070*** (1.098)
Charge system 2	-82.151*** (23.694)	-0.160 (0.187)	-27.402*** (2.955)	-8.847*** (1.894)	-30.408 (19.884)	-0.844 (0.730)	18.373 (20.810)	-0.349 (0.536)
Charge system 3	-103.012*** (23.735)	1.320*** (0.226)	-27.003*** (3.207)	-6.968*** (1.965)	-34.566* (20.261)	-0.618 (0.714)	12.530 (21.249)	4.722*** (1.339)
Charge system 4	-162.608*** (23.730)	5.873*** (0.239)	-59.915*** (3.150)	-3.628* (1.941)	-90.514*** (20.185)	5.047*** (0.745)	10.952 (21.083)	6.254*** (1.141)
Charge system 5	-213.357*** (23.755)	6.761*** (0.587)	-16.735*** (4.129)	-5.785*** (2.055)	-137.437*** (21.034)	4.841 (3.449)	44.328** (21.913)	4.293** (1.679)
Charge system 6	-223.793*** (23.792)	7.355*** (0.688)	21.442*** (4.328)	-0.052 (1.994)	-132.012*** (21.990)	5.510** (2.588)	29.992 (22.000)	4.835* (2.771)
Charge system 8	-184.507*** (23.744)	9.333*** (0.772)	-95.269*** (3.191)	0.472 (2.037)	-125.619*** (20.804)	5.834** (2.571)	-28.113 (21.970)	8.254** (3.378)
Charge system 9	-174.875*** (23.777)	6.299*** (0.522)	-90.408*** (3.810)	-1.367 (1.978)	-102.771*** (20.458)	8.933*** (1.961)	-13.891 (23.062)	6.530** (2.564)
Population density	0.009*** (0.001)	-0.001*** (0.000)	-0.025*** (0.000)	-0.007*** (0.000)	-0.004 (0.005)	-0.003 (0.002)	-0.011* (0.006)	0.001 (0.002)
Constant	318.566*** (23.781)	-0.151 (0.451)	164.354*** (3.254)	87.604*** (1.992)	273.093*** (20.047)	2.162 (1.681)	100.223*** (21.295)	71.643*** (1.259)
Observations	8,779	3,113	8,713	8,652	8,779	3,113	8,713	8,652
Number of municipalities	560	447	559	558	560	447	559	558
Year dummies	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	NO	NO	NO	NO	YES	YES	YES	YES

Note: Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Fixed effects are on municipality level. Waste charge systems 1,2 and 3 are calculated based on fixed charges, charges based on household size and the volume of the garbage can. The other systems are estimated based on how often a garbage can is emptied (4), number of bags collected (5), number of bags and household size (6), the total weight (8) and weight combined with number of pickups (9).

In Table 5 the effect of the European directive is investigated. When looking specifically at the impact of the directive alone, there is a large reduction in household waste and smaller reductions in biodegradable waste and paper and cardboard. As the implementation of the directive is only measured in one year, this effect is a year-fixed effect. When combining the impact of the directive with the diftar system, the associated overall effect for biodegradable waste shows a small increase in waste of around 4 kilograms. The overall effects that are found for household residuals show that there is a reduction in this waste type of around 80 kilograms. With respect to paper and cardboard the overall effect seems to be zero where the diftar system and the directive seem to cancel out.

When introducing fixed effects in Columns 5 through 8 the overall effects of the directive and diftar system for household residual waste is less strong, but similar in nature. The overall effect for paper and cardboards stays around zero. The overall effect of biodegradable waste shows a larger increase in waste.

These findings could be explained by the awareness objective that is part of the directive. By raising awareness, the overall amount of waste is greatly reduced in the category of household residuals. For the other categories, the effects are smaller but still point towards an improvement in terms of separating waste types. If biodegradable waste would previously be part of the household residual waste for some households due to no waste separation, separating biodegradable waste could increase due to the increased awareness of the importance of separating waste. As individuals are most likely already separating paper and cardboard, as it is collected by schools and sport clubs, there is no extra increase or reduction found. Individuals are already separating this waste type and will keep doing so after the implementation of the directive.

The results of Table 5 suggest that there is an overall reduction in waste due to the directive. However, the total biodegradable waste increased. This might be due to the increased separation efforts of individuals as they are more aware of the importance of separating waste sources due to the directive.

**Table 5: Regression effect directive**

	(1) Household residual	(2) Plastic	(3) Biodegradable	(4) Paper/Cardboard	(5) Household residual	(6) Plastic	(7) Biodegradable	(8) Paper/Cardboard
Diftar	-93.741*** (1.069)	6.456*** (0.175)	-27.425*** (1.085)	6.474*** (0.328)	-67.413*** (3.206)	6.129*** (0.869)	-8.909*** (3.259)	5.992*** (0.836)
Diftar x Directive	12.124** (6.141)	-8.881*** (1.226)	31.157*** (3.905)	-6.438*** (1.586)	10.741*** (3.578)	-11.439*** (0.557)	17.249*** (2.596)	-5.460*** (0.803)
Population density	0.010*** (0.001)	-0.001*** (0.000)	-0.025*** (0.000)	-0.007*** (0.000)	-0.003 (0.005)	-0.003 (0.002)	-0.012* (0.006)	0.001 (0.002)
Constant	235.170*** (2.489)	-0.006 (0.419)	135.278*** (1.577)	78.387*** (0.687)	241.297*** (4.308)	1.595 (1.734)	119.134*** (5.035)	71.170*** (1.343)
Observations	8,779	3,113	8,713	8,652	8,779	3,113	8,713	8,652
Year dummies	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	NO	NO	NO	NO	YES	YES	YES	YES
Number of municipalities	560	447	559	558	560	447	559	558

Note: Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Fixed effects are on municipality level.

## **5.2. Robustness checks**

To make sure the results found in chapter 5.1 are not influenced by manual alterations due to municipalities joining together, the most important estimations are repeated in this section without the altered municipalities. These are the estimation of the effect of the diftar system and secondly combining this effect with the effect of the European directive.

The effect of the diftar variable that is estimated in Table 3 in Columns 5 through 8 is repeated in Table 6 in the first four columns. Both the magnitude and sign of the results is very similar in both situations. These results show that for the diftar estimation the manually altered municipalities seem to have no influence on the result. For the Columns 5 through 8 of Table 6, the same estimation is done as shown in Table 5 Columns 5 through 8. Similar as in the diftar case, the estimated coefficients are not altered by significant amounts and keep the same sign and magnitude. All in all these results show that the manual alteration of merging municipalities does not influence the results.

**Table 6: Robustness checks**

	(1) Household residual	(2) Plastic	(3) Biodegradable	(4) Paper/Cardboard	(5) Household residual	(6) Plastic	(7) Biodegradable	(8) Paper/Cardboard
Diftar	-66.624*** (3.190)	6.102*** (0.882)	-7.187** (3.230)	5.666*** (0.863)	-67.429*** (3.222)	6.171*** (0.868)	-8.544*** (3.293)	6.077*** (0.856)
Diftar x Directive					10.266*** (3.626)	-12.066*** (0.613)	17.061*** (2.620)	-5.391*** (0.815)
Population density	-0.005 (0.006)	-0.003 (0.002)	-0.018** (0.008)	0.002 (0.002)	-0.005 (0.006)	-0.003 (0.002)	-0.017** (0.008)	0.002 (0.002)
Constant	242.529*** (5.169)	1.492 (1.817)	123.372*** (6.103)	70.543*** (1.555)	242.372*** (5.171)	1.522 (1.824)	123.074*** (5.935)	70.602*** (1.528)
Observations	8,581	3,040	8,514	8,457	8,581	3,040	8,514	8,457
Number of gemeente	546	444	545	544	546	444	545	544
Year dummies	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES

Note: Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Fixed effects are on municipality level.

## 6. Conclusion

The increasing amount of waste is a growing concern in the European Union. With growing population sizes, the waste amounts are expected to grow further if no-one intervenes. Multiple ideas have been put forward to find a solution. In the Netherlands, a variable waste charge (diftar) is implemented in a number of municipalities. By charging individuals for the amount of waste they present for collection, they are incentivized to reduce the amounts of waste they produce. Apart from national initiatives, the European Union drafted a directive to reduce the amount of (plastic) waste and thereby protecting both oceans and human health. By raising awareness of the hazards of waste and focusing on the importance of recycling and reduction, the directive aims to implement a continent-wide solution for plastic waste.

By using datasets covering the amount of waste and municipality information from Statistics Netherlands and COELO about the used diftar systems in municipalities an insight into the effectiveness of the diftar system is given using an OLS-regression with and without the use of municipality fixed effects. The results are estimated with data over a time span of 2001 until 2022. At the beginning of the time period around 460 municipalities were in the datasets, however, over time municipalities merged with other municipalities reducing the number of municipalities to around 340 at the end of the timeframe. Based on the descriptive statistics, municipalities that are more urban refrain from implementing diftar measures. This is the case because implementation of this system is more difficult in highly populated areas.

The regression results show that the implementation of a diftar waste charge system is associated with a reduction in the waste types of household residual waste and biodegradable waste. However, for the waste types of plastic and paper and cardboard, the amount of waste is increasing. As the collection of these waste types is less frequent, and for paper and cardboard mostly done by schools and sport clubs for free, the results suggest that individuals separate their waste better. Due to the better separation when a diftar waste charge is implemented, plastic and paper waste are taken out of household residual waste causing an increase in the two waste categories. However, the reduction in household residual is larger, which is likely due to the incentive of reduced waste charges when total waste amounts are reduced. These findings are similar to the conclusions of De Bruin, Oldenhof & Nijmeijer (2021) and show the effectiveness of the diftar system with respect to both the reduction of waste and separation at the source.

When investigating the difference between weight-based and volume-based diftar systems, the results of this paper suggest that for waste types that are heavier a weight-based system is more effective to reduce the amount of waste. This finding could be explained by a larger monetary incentive for

marginal reductions in the overall waste amount. However, for household residual waste the volume-based diftar methods seem to be more effective. One explanation for this finding is that bulkier waste is better separated, to reduce the waste charge. This would also result in a larger reduction of overall waste in kilograms. Based on the findings of this paper, the conclusion of Allers and Hoeben (2009) that weight-based diftar systems are more effective in reducing the amount of waste compared to volume-based systems, is specified further towards the heavier waste types like biodegradable waste.

Lastly, the overall effect for the European directive is separated in a reduction for household residual waste and an increase in biodegradable waste. This finding might be influenced by behavioural changes in the way individuals separate their waste, as discussed by Nuojuua, Pahl and Thompson (2024). By separating other waste types, like biodegradable waste, out of the household residual waste, the residual waste would decrease in weight. Other waste categories would as a result grow in size. Based on the results, the directive is therefore mostly associated with having an effect on separation at the source. The overall impact on the composition of the waste composition in municipalities in the Netherlands is therefore a decrease in household residual waste due to better separation at the source.

## 7. Limitations and suggestions

Directive 2019/904 was drafted and signed in 2019. However, the implementation in the Netherlands took place in July 2021. Due to the date of implementation, only one full year where the directive was implemented is part of the dataset. Therefore, the estimated effect of the directive is likely to be influenced by factors of the year 2022. Moreover, due to the limited data available it is impossible to estimate long term effects of the implementation. As the directive aims to reduce the amount of plastic waste, it is important for future research to investigate the effects of the directive on the long-term use of plastics. Moreover, in recent years, an increasing number of municipalities in the Netherlands did not report the amount of plastic waste that was collected. This caused for a gap in the dataset which resulted in the inability of giving conclusions about the effects with respect to plastic waste.

The estimation of the diftar waste system could be slightly biased. As municipalities are able to choose the waste charge system that they will use, the zero conditional mean assumption does not hold. Municipalities mainly based their system choice on the systems that were implemented in surrounding municipalities. Moreover, population density plays a significant role in the selection process. To limit the bias that would exist because of the choice of waste charges both municipality fixed effects and the population density are included into the estimation. To properly estimate a causal effect of the diftar system, a random experiment could be implemented. This would cause the zero conditional mean assumption to hold since municipalities are unable to choose charge systems for themselves.

However, the findings of the paper show that a lot can be done with regard to the reduction of waste. It is important to note that the results suggest that different types of waste require different waste charge methods to reduce them. For example, heavier waste types require weight-based charge system for the largest reduction. Further research is required into effective methods of waste reduction as the results of this paper show that policy measures into waste reduction should be tailor made to the waste type. Moreover, investigations should be made to identify more possibilities to implement diftar systems in other municipalities with higher population density as diftar systems seem to be effective in reducing waste.

Due to the importance of reducing the amount of plastic waste that is produced for both human health and the protection of wildlife, there should be continuous research into these issues. By identifying the effects of policies, it is possible to further improve them, to better protect ourselves and the world as a whole.

## References

- Adam, I. et al. (2020). Policies to reduce single-use plastic marine pollution in West Africa. *Marine Policy*, 116, 103928.
- Allers, M. A., & Hoeben, C. (2010). Effects of unit-based garbage pricing: A differences-in-differences approach. *Environmental & Resource Economics*, 45(3), 405-428.  
<https://doi.org/10.1007/s10640-009-9320-6>.
- Aristei, Luna. (2022). A Plastic Word. Ups and Downs in the National Application of Directive 2019/904/EU. *Italian Journal of Public Law*, 14(2), 490-520.
- Bartelings, H., & Sterner, T. (1999). Household waste management in a Swedish municipality: determinants of waste disposal, recycling and composting. *Environmental and resource economics*, 13, 473-491.
- Bel, G., Dijkgraaf, E., Fageda, X., & Gradus, R. (2010). Similar problems, different solutions: Comparing refuse collection in the Netherlands and Spain. *Public Administration*, 88(2), 479-495.
- Van Beukering, P. J., H. Bartelings, V. G. Linderhof, & Oosterhuis, F. H. (2009) Effectiveness of unit-based pricing of waste in the Netherlands: Applying a general equilibrium model, *Waste management*, 29(11), p. 2892-2901.
- Bharti, R., & Sharma, R. (2021). Analysis of plastic waste management: Utilization, issues & solutions. *Materials Today: Proceedings*, 45, p. 3625-3632.
- De Bruin, P.M.J., Oldenhof, R.H.F., Nijmeijer, E. (2021). Diftar als beleidsinstrument bij huishoudelijk afvalbeheer. *IPR Normag*. In opdracht van Rijkswaterstaat.
- Burton, A. L. (2021). OLS (Linear) regression. *The encyclopedia of research methods in criminology and Criminal Justice*, 2, p. 509-514.
- Charitou, A., Aga-Spyridopoulou, R. N., Mylona, Z., Beck, R., McLellan, F., & Addamo, A. M. (2021). Investigating the knowledge and attitude of the Greek public towards marine plastic pollution and the EU Single-Use Plastics Directive. *Marine pollution bulletin*, 166, 112182.
- Cook, C. R., & Halden, R. U. (2020). Ecological and health issues of plastic waste. In *Plastic waste and recycling* (pp. 513-527). Academic Press.
- Daskalopoulos, E., Badr, O., & Probert, S. D. (1998). Municipal solid waste: a prediction methodology for the generation rate and composition in the European Union countries and the United States of America. *Resources, conservation and recycling*, 24(2), 155-166.
- Dijkgraaf, E., & Vollebergh, H. R. (2004). Burn or bury? A social cost comparison of final waste disposal methods. *Ecological Economics*, 50(3-4), 233-247.
- Dijkgraaf, E., & Gradus, R. H. (2004). Cost savings in unit-based pricing of household waste: The case of The Netherlands. *Resource and energy economics*, 26(4), 353-371.
- Dijkgraaf, E. and R.H.J.M. Gradus. (2007). 'Collusion in the Dutch Waste Collection Market', *Local Government Studies*, 33, 4, 573-88.
- Dijkgraaf, E., & Gradus, R. (2017). An EU recycling target: what does the Dutch evidence tell us?. *Environmental and Resource Economics*, 68, 501-526.

- Directive 2019/904. *Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.* <http://data.europa.eu/eli/dir/2019/904/oj>.
- European Commission. (2020). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A new Circular Economy Action Plan for a cleaner and more competitive Europe (COM/2020/98 final)*. Brussels, Belgium: European Commission.
- Gómez, I. D. L., & Escobar, A. S. (2022). The dilemma of plastic bags and their substitutes: A review on LCA studies. *Sustainable Production and Consumption*, 30, 107-116.
- Gómez, V. A., Pozo, K., Clérandeau, C., Cachot, J., Montes, C., Příbylová, P., ... & Morin, B. (2023). Plastic debris, persistent organic pollutants and their toxicity impacts in coastal areas in Central Chile. *Marine Pollution Bulletin*, 194, 115361.
- Goorhuis, M., Reus, P., Nieuwenhuis, E., Spanbroek, N., Sol, M., & van Rijn, J. (2012). New developments in waste management in the Netherlands. *Waste management & research*, 30(9), 67-77.
- Groot, J., Bing, X., Bos-Brouwers, H., & Bloemhof-Ruwaard, J. (2014). A comprehensive waste collection cost model applied to post-consumer plastic packaging waste. *Resources, Conservation and Recycling*, 85, 79-87.
- Heijnen, P., & Elhorst, J. P. (2018). The diffusion of local differentiated waste disposal taxes in the Netherlands. *De Economist*, 166, 239-258.
- Hurmelinna-Laukkanen, P., Paukku, E., & Taskila, S. (2021). Innovation Management Responses To Regulation—Sup-Directive And Replacing Plastic. *International Journal of Innovation Management*, 25(10), 2140004.
- Kaszniak, D., & Łapniewska, Z. (2023). The end of plastic? The EU's directive on single-use plastics and its implementation in Poland. *Environmental Science & Policy*, 145, 151-163.
- Kehinde, O., Ramonu, O. J., Babaremu, K. O., & Justin, L. D. (2020). Plastic wastes: environmental hazard and instrument for wealth creation in Nigeria. *Heliyon*, 6(10).
- Kiessling, T., et al. (2023). What potential does the EU Single-Use Plastics Directive have for reducing plastic pollution at coastlines and riversides? An evaluation based on citizen science data. *Waste Management*, 164, 106-118.
- Lee, J., & Jeong, S. (2023). Approach to an answer to “how dangerous microplastics are to the human body”: a systematic review of the quantification of MPs and simultaneously exposed chemicals. *Journal of Hazardous Materials*, 132404.
- Letcher, T., et al. (2020). *Plastic waste and recycling: Environmental impact, societal issues, prevention, and solutions*. Academic Press.
- Meng, F., Brandão, M., & Cullen, J. M. (2024). Replacing plastics with alternatives is worse for greenhouse gas emissions in most cases. *Environmental Science & Technology*, 58(6), 2716-2727.
- Minelgaitė, A., & Liobikienė, G. (2019). Waste problem in European Union and its influence on waste management behaviours. *Science of the Total Environment*, 667, 86-93.

- Moore, C. J., Moore, S. L., Leecaster, M. K., & Weisberg, S. B. (2001). A comparison of plastic and plankton in the North Pacific central gyre. *Marine pollution bulletin*, 42(12), 1297-1300.
- Nikitara, K., Lagou, I., Plyta, Z., Mocanu, K., & Vardavas, C. (2022). The EU single-use plastics directive and its impact on tobacco products: a policy analysis. *Public Health Toxicology*, 2(3), 1-4.
- Nuojua, S., Pahl, S., & Thompson, R. C. (2024). Plastic alternatives and substitutes in the packaging sector—A UK consumer perspective. *Sustainable Production and Consumption*, 46, 68-81.
- OECD (2020). Recommendation of the Council on Guiding Principles concerning International Economic Aspects of Environmental Policies, OECD/LEGAL/0102.
- Rijkswaterstaat (2024). Afvalverwerking in Nederland: gegevens 2022 / Werkgroep Afvalregistratie. – Utrecht : Rijkswaterstaat.
- Schmidt, S., & Laner, D. (2021). The multidimensional effects of single-use and packaging plastic strategies on German household waste management. *Waste Management*, 131, 187-200.
- Stoeva, K., & Alriksson, S. (2017). Influence of recycling programmes on waste separation behaviour. *Waste Management*, 68, 732-741.
- Syberg, K., Nielsen, M. B., Clausen, L. P. W., Van Calster, G., Van Wezel, A., Rochman, C., ... & Hansen, S. F. (2021). Regulation of plastic from a circular economy perspective. *Current opinion in green and sustainable chemistry*, 29, 100462.
- Van der Werff, E., Vrieling, L., Van Zuijlen, B., & Worrell, E. (2019). Waste minimization by households—A unique informational strategy in the Netherlands. *Resources, Conservation and Recycling*, 144, 256-266.

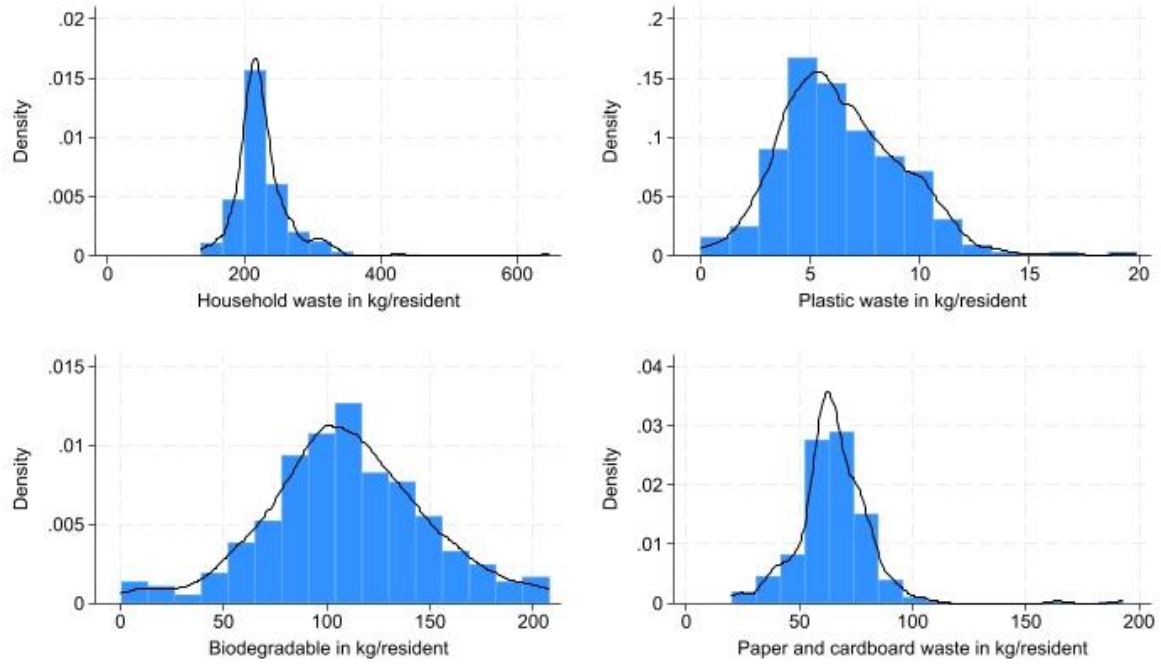
## Appendix

**Table A1: Descriptive statistics by waste charge system**

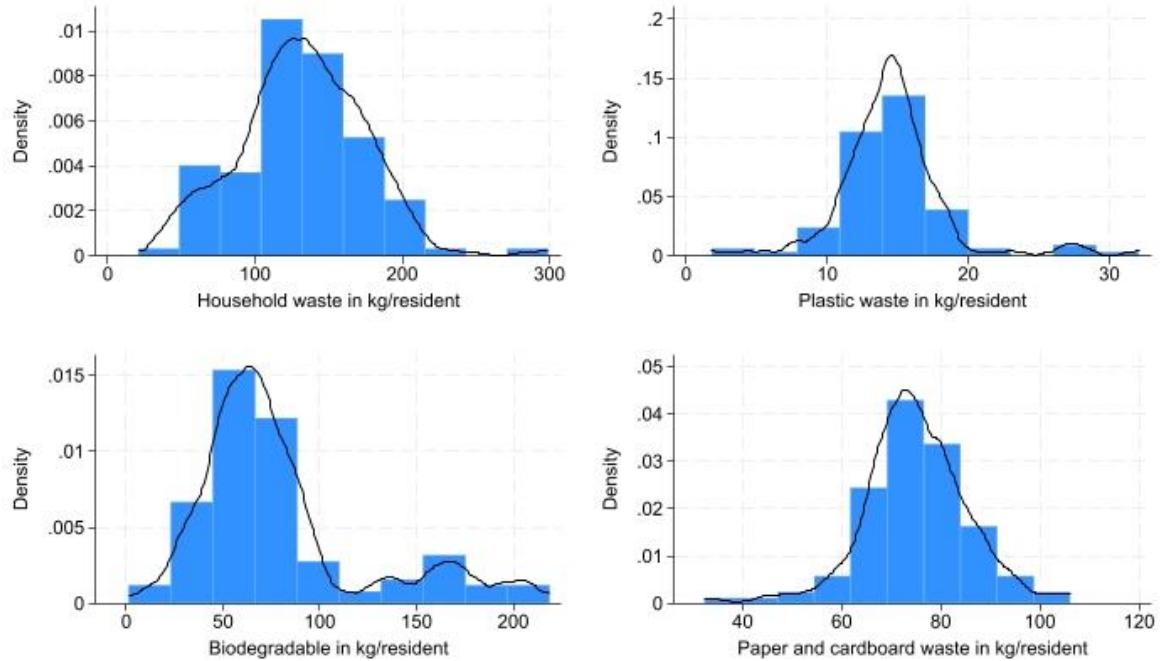
	2007			2012			2017			2022		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
<b>Charge System 1</b>												
Municipality population	41	66.404	101.661	32	72.003	111.402	25	56.136	57.576	10	49.439	44.316
Population density	41	1.225	969	32	1.233	960	25	1.112	883	10	990	535
Household size	41	2,32	0,17	32	2,26	0,14	25	2,23	0,15	10	2,15	0,18
Woz-value (x100.000)	41	209	46	32	226	48	25	204	40	10	286	58
Dutch background	41	83,03%	8,54%	32	81,32%	9,35%	25	81,03%	8,75%	10	79,51%	9,37%
<b>Charge System 2</b>												
Municipality population	255	37.746	61.593	229	43.142	70.428	186	53.773	91.792	150	67.230	106.373
Population density	255	865	1057	229	948	1144	186	1.048	1.232	150	1.294	1.352
Household size	255	2,39	0,20	229	2,33	0,20	186	2,26	0,20	150	2,21	0,20
Woz-value (x100.000)	255	237	67	229	252	66	186	231	65	150	334	95
Dutch background	255	87,31%	7,81%	229	86,36%	8,08%	186	83,84%	9,26%	150	79,63%	10,79%
<b>Charge System 3</b>												
Municipality population	35	30.661	25.098	34	32.590	26.201	20	39.783	33.593	9	47.136	43.699
Population density	35	564	684	34	498	462	20	778	921	9	660	909
Household size	35	2,49	0,15	34	2,44	0,16	20	2,33	0,12	9	2,30	0,14
Woz-value (x100.000)	35	252	45	34	271	56	20	260	95	9	410	185
Dutch background	35	88,78%	5,80%	34	88,36%	7,09%	20	84,96%	6,60%	9	84,93%	7,81%
<b>Charge System 4</b>												
Municipality population	67	25.909	19.982	76	28.647	21.280	109	31.473	24.357	116	37.235	25.046
Population density	67	381	351	76	472	462	109	512	507	116	579	631
Household size	67	2,53	0,19	76	2,38	0,16	109	2,32	0,15	116	2,27	0,15
Woz-value (x100.000)	67	246	46	76	245	55	109	223	44	116	314	60
Dutch background	67	90,98%	4,33%	76	88,38%	7,09%	109	87,17%	6,82%	116	85,36%	6,73%

<b>Charge System 5</b>												
Municipality population	10	29.477	32.081	12	30.894	30.311	19	35.810	41.285	33	40.411	40.694
Population density	10	669	579	12	544	527	19	579	787	33	544	651
Household size	10	2,43	0,25	12	2,37	0,23	19	2,32	0,24	33	2,28	0,18
Woz-value (x100.000)	10	252	37	12	265	40	19	222	36	33	323	56
Dutch background	10	86.80%	5,57%	12	86,87%	6,47%	19	88,03%	6,82%	33	85,75%	7,31%
<b>Charge System 6</b>												
Municipality population	10	32.687	46.117	8	34.519	53.039	8	23.274	10.228	8	28.527	11.698
Population density	10	838	958	8	773	952	8	509	418	8	707	614
Household size	10	2,44	0,22	8	2,31	0,21	8	2,29	0,08	8	2,25	0,09
Woz-value (x100.000)	10	258	35	8	261	40	8	241	22	8	321	32
Dutch background	10	87,64%	5,60%	8	86,70%	5,56%	8	87,79%	2,99%	8	83,38%	4,05%
<b>Charge System 8</b>												
Municipality population	18	22.933	19.742	13	18.199	8.612	10	17.227	8.015	4	24.137	27.183
Population density	18	485	340	13	301	186	10	253	132	4	225	161
Household size	18	2,41	0,11	13	2,39	0,11	10	2,34	0,10	4	2,26	0,08
Woz-value (x100.000)	18	229	39	13	248	40	10	225	37	4	322	45
Dutch background	18	88,52%	4,43%	13	90,93%	3,64%	10	91,30%	3,21%	4	85,48%	7,82%
<b>Charge System 9</b>												
Municipality population	6	24.537	15.288	9	32.529	26.019	10	39.831	28.366	11	40.800	21.624
Population density	6	368	198	9	650	360	10	639	354	11	528	418
Household size	6	2,61	0,15	9	2,36	0,17	10	2,25	0,12	11	2,18	0,08
Woz-value (x100.000)	6	293	28	9	253	62	10	207	38	11	270	40
Dutch background	6	91,70%	4,65%	9	87,13%	5,33%	10	85,63%	4,48%	11	86,13%	5,68%

Note: Waste charge systems 1,2 and 3 are considered non-diftar and the charges are calculated based on fixed charges, charges based on household size and the volume of the garbagecan respectively. The other systems are considered diftar systems and calculate the charge based on how often a garbagecan are emptied (4), number of bags collected (5), number of bags and household size (6), the total weight (8) and weight combined with number of pickups (9).



**Figure A1: Non-diftar municipality density per waste category and amount of waste in 2012**



**Figure A2: Diftar municipality density per waste category and amount of waste in 2012**