Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Economics

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Master's Thesis • 30 hec • Advanced level
Environmental Economics and Management – Master's Programme
Degree thesis No 1090 • ISSN 1401-4084
Uppsala 2017

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Credits: 30 hec
Level: A2E
Course title: Independent project in economics
Course code: EX0811
Programme/education: Environmental Economics and Management – Master's Programme

Place of publication: Uppsala
Year of publication: 2017
Title of series: Degree project/SLU, department of Economics
Part number: 1090
ISSN: 1401-4084
Online publication: http://stud.epsilon.slu.se

Keywords: environmental behaviour, waste sorting degree, curbside recycling, food waste, packaging waste

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Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences

Abstract

Introduction of residential curbside recycling programs are assumed to have a positive effect on households' waste sorting effort since it facilitates recycling in the context of daily life and provides a lower behavioural cost in terms of time, effort and storage cost compared to drop-off recycling. In Sweden, three different systems for curbside collection are used for waste sorting; four-compartment bins, different coloured bags, and bags and containers. The purpose of this study is to empirically evaluate curbside recycling program and to estimate the change in waste sorting effort in Swedish municipalities when residents living in single-family houses makes a transition from drop-off recycling to curbside recycling of packaging waste and newspaper. Econometric regression models are applied on unbalanced panel data for 264 municipalities during the time period 2007-2015. Fixed-effect regression model are used with additional control for region-specific characteristics and for waste management policies used. The results indicate a significant but weak support for a better waste sorting behaviour among municipalities providing curbside recycling with different coloured bags.

Table of Content

List of Tables

List of Figures

1 Introduction

A country with rising income will produce more waste over time due to changes in consumption patterns. Policymakers and governments must therefore promote recycling among households in order to reduce the amount of waste (Sterner et al, 2012). European Union (EU) waste management policies therefore prioritise prevention, reuse, material recycling, energy recovery, and disposal of waste (EU 2008/98/EG). This waste management hierarchy is incorporated into the Swedish Environmental Code [Miljöbalken] which makes recycling and waste reduction programs important from a policy instrument perspective (SOU 2017:22). The aim with the waste management hierarchy is to reduce the environmental impact caused by waste.

Due to its importance, a large amount of political effort is devoted to promoting recycling in Sweden and extensive legislation requires recycling of various categories of waste. One of the more prominent polices within this area is the Producers' Responsibility Ordinance established in 1994. According to the ordinance, packaging waste of plastic, glass, metal, paper and newspaper must be separated from other waste since this waste is intended for material recycling. The ordinance requires Swedish producers of packaging materials to provide a collection system for packaging waste. Hence, the producers have the physical and economic responsibility for the packaging waste and must collect, remove and recover the waste from consumers (EU/94/62/EG). Since the ratification of the ordinance, about 6000 drop-off stations in which households can leave their packaging waste have been establish (SWMA, 2016c). Moreover, the ordinance requires households to separate packaging waste from other waste, clean the waste, transport the waste to collection systems at recycling stations, and there sort different packaging materials in assigned recycling bins. The cost of recycling packaging material is added to the price of the product. Hence, the consumer pays for the recycling when buying packaged products, regardless of their decision to recycle or not. Whether households comply with the environmental regulation and recycle packaging waste is rarely checked, even if their participation is mandatory. Local authorities have incorporated additional waste management policies such as unit pricing and curbside collection of household waste to increase the waste sorting effort among Swedish households (SWMA, 2016c). The number of municipalities offering curbside collection of packaging waste and newspaper has increased over the years. However, there is no uniform system among Swedish municipalities and several systems for waste sorting are used.

Waste management policy is a well-studied research area within economics. Yet little attention has been given to the question of the level of waste sorting arising with different collection systems. According to the foundations of microeconomic theory, the choice to recycle will be a decision based on trade-offs between various options. Previous studies have tried to understand why individuals participate in recycling activities (Bruvoll Halvorsen & Nyborg, 2002; Hage & Söderholm, 2008), as well as how policymakers can encouraging further recycling by using different policy instruments (Andersson & Stage, 2017; Ek & Muiliute-Plepiene, 2016; Dahlén et al, 2007). The results show that individuals are driven by economic incentives and norm-based motives, which influence their waste sorting behaviour. However, although curbside collection has received previous attention, not many studies have looked into the impact that different curbside collection systems used for waste sorting has on the waste sorting degree.

1.1 Aim and research question

Against this backdrop, the general objective of this study is to examine if waste sorting among Swedish households is stimulated by municipal policies that lower the opportunity cost for recycling in terms of time and effort. The research questions this thesis aims to answer are therefore: How does the waste sorting degree among Swedish households change when households living in single-family houses makes a transition from drop-off recycling to curbside recycling of packaging waste and newspaper? Moreover, is there a difference in effect of three different waste sorting systems used for curbside recycling?

In order to answer the research questions, an analysis will be done by using an econometric model based on an unbalanced panel containing waste-related data for 264 municipalities in Sweden during the time period 2007 to 2015. Each observation is defined as a municipality (*i*) in a given year (*t*). The households' waste sorting behaviour is measured by a variable capturing the waste sorting degree in a municipality in a given year. Hence, the proportion of collected household waste intended for material- and biological recycle separated from the total amount of collected household waste. The ratio is calculated by using waste-related data on a municipal level obtained from Avfall Web. However, the chosen indicator for waste sorting effort do not capture waste composition. Therefore, wrongly sorted materials or hazardous waste thrown in the waste bin are not captured. Hazardous waste, bulky waste and yard waste are usually collected separately and taken to recycling centres. These are, therefore, not included in this study.

Two methods are used for the estimation of the effects from different curbside collection system used on households' waste sorting efforts. First, regression models with a difference-in-difference design are used in order to estimate the effect of a transition from drop-off recycling to curbside recycling. This model is later extended to estimate the effect on waste sorting behaviour over time using lagged values of the independent variable. Second, a continuous treatment variable is used, estimating the effect of an increase in the share of single-family households participating in curbside recycling.

The thesis is structured as follows. Section 2 gives an introduction to waste management policies used in Sweden, followed by a literature review of previous studies within the field of waste management. A theoretical framework used to understand recycling behaviour among households is presented in section 3. In section 4 the data is presented, followed by the method and regression models used in section 5. The results from the regression models are presented in section 6. The results are followed by a discussion and concluding remarks.

2 Background

In the following section an introduction to waste management policies in Sweden is made, followed by an explanation of three different systems for curbside collection used for waste sorting; four-compartment bins, bags and containers and different coloured bags. Furthermore, previous studies within the field of waste management are presented.

2.1 Waste management in Swedish municipalities

Recycling policy goals are formulated at national level in Sweden. But the primary responsibility for policy implementations is assigned to local governments on a municipal level. As a result of decentralized responsibility regarding waste management, recycling outcomes differ across the country (Hage & Söderholm, 2008). The Swedish municipalities are responsible for the collection and disposal of household waste not covered by the producer ordinance. Each municipality is required to have its own waste management plan including all waste streams in the region, and in cooperation with the producers of packaging material establish drop-off systems for packaging waste going to material recycling. The municipal waste management plan includes strategies of how to prevent and reduce the amounts of waste in line with the Environmental Code and the waste management hierarchy (SOU, 2012:56). To increase the waste sorting effort among Swedish households, local authorities have incorporated additional waste management policies to the producer ordinance, such as unit pricing, either with a volume or weight-based collection fee, and curbside collection of household waste, either of food waste and/or packaging waste. With a weight-based collection fee households are charged for each kilogram of waste they throw which provides economic incentives for individuals to increase their waste sorting effort. 30 municipalities applied weight-based collection fees for single-family houses in 2015. The fee varies between 0.90-3.75 SEK per kilogram of residual waste and 0-3.69 per kilogram of food waste (SWMA, 2016c).

Curbside collection can be seen as an increased service that makes recycling more available for the households. The number of municipalities offering curbside collection of packaging waste and newspaper as a complement to drop-off recycling for resident living in single family houses has increased during the last 10 years (Ek & Miliute-Plepiene, 2016).. Introduction of curbside collection is assumed to have a positive effect on household recycling efforts by facilitating waste sorting in the context of daily life. With curbside collection, more packaging and paper waste are expected to be recycled. Approximately 10 percent of Swedish families living in single-family houses have access to curbside recycling. For apartment households the participation rate is about 40 percent (SWMA, 2016b). However, there is no uniform curbside collection system used for waste sorting among single-family households. The different collection system requires the households to separate waste in different ways.

2.1.1 Waste sorting systems used in Swedish municipalities

The most common way to separate household waste is into two four-compartment bins (SWMA 2016b). The collection system offers an integrated solution for waste sorting of residual waste, food waste, and packaging waste of all materials.[1] No intermediate storage for packaging waste is needed in the kitchen or elsewhere since households can throw recyclables directly into the bins outside (SWMA, 2014).

Another way to separate and sort household waste is in different types of containers, buckets, boxes or bags. The system has been used for several years in some of the municipalities and can be seen as the first generation of curbside recycling. The design, however, differs somewhat between the municipalities - something that is assumed to have an impact on the waste sorting effort (SWMA, 2014). This system requires households to separate waste into coloured bags and place them in the same sack or bin. The bags are thereafter sorted manually at a sorting facility. Paper and glass are often handled separately and placed in a separate bin or left at a drop-off stations. The system can give an aesthetic impression with several buckets, boxes and bags at the property and the use of different types of containers involve relatively high amount of administration for the households (SWMA, 2014).

The third system used for waste sorting requires households to separate waste into different coloured bags and place them in the same bin. This system offers an integrated solution for collection of residual waste, food waste and packaging waste of all fractions except glass, which must be recycled at the recycling station. The bags are later sorted by colour in an optical sorting facility. In order to be sorted effectively it must be clearly indicated which coloured bag that is intended for each fraction. Furthermore, it is also important that bags are distributed in a smooth manner and bags always are available for waste sorting. With this waste system households need intermediate storage of recyclables in the kitchen or elsewhere before throwing the bags in the waste bin (SWMA, 2014).

2.2 Results from previous studies

Several papers estimate the effect of different waste management policy instrument on household waste behaviour, based on Swedish conditions. Previous studies have estimated the effect of weight-based collection fees as well as the effect of curbside collection of food waste and/or packaging waste on households' waste sorting effort. Some previous research

[1] Packaging waste of plastic, glass, metal, paper and newspaper

have done case studies of municipalities in order to describe the impact of socio-economic factors on recycling behaviour (Dahlén et al, 2007), while other studies have used econometric analysis to identify the determinants of recycling effort (Anderson & Stage, 2017; Ek & Miliute-Plepiene, 2016). However, no previous study estimates the effect of different curbside collection systems used for waste sorting using econometric analysis.

Previous research has shown that economic incentives in the form of a weight-based collection fee has a significant waste-reduction effect. Hage and Söderholm (2008) found increasing collection rates of plastic packaging waste when municipalities employed weigh-based collection fees, controlling for region-specific characteristics as demographic, socio-economic variables and environmental preferences, by using regression analysis on a cross-sectional data for 252 Swedish municipalities for the year 2002. However, economic incentives were not the only explanatory variable behind individuals' waste sorting effort. The collection of plastic packaging increased if the municipality increased the number of drop-off stations per capita. Furthermore, households living in multi-family houses with access to curbside recycling recycled more packaging waste.

Another waste management policy instrument used to increase households waste sorting effort is collection of food waste. Ek and Miliute-Plepiene (2016) examine whether introduction of food waste collection among Swedish municipalities increase waste sorting efforts of packaging waste. Curbside collection of household waste was included as a control variable, showing a significant and positive effect on the quantity of collected packaging waste. In a similar study, Andersson and Stage (2017) estimate the effect of using weight-based collection fee as well as collection of food waste on the total amount of households waste collected in Swedish municipalities. Both studies apply a fixed-effect regression analysis with panel data for approximately 250 Swedish municipalities between 2006/2007 and 2014 with data from Avfall Web. Both studies find an increased waste sorting effort of packaging waste and a reduced amount of bin and bag waste with separate collection of food waste.

Since households recycle without direct economic incentives to do so, the choice to recycle are assumed to be influenced by motives other than purely economic incentives. Bruvoll, Halvorsen and Nyborg (2002) found that norm-based motives and attitudes towards the environment were important determinants for waste sorting efforts. In a stated preference survey conducted in 1999, 1162 Norwegian households were asked about their waste sorting behaviour. 82 percent of the respondents believed that waste separation and recycling contributed to a better environment, however, most of the respondents who did not believe that sorting led to a better environment did sort anyway. Most of the respondent engaged in waste sorting because they wanted to contribute to a better environment and because they wanted to act in the same way the wished others to do. 73 percent sorted their waste because they wished to think of themselves as responsible individuals. Moreover, the authors found that individuals were spending time on sorting waste accordingly: in average 30 minutes a week was spent on cleaning, sorting, and transporting recyclable waste to recycling stations. In a similar study Hage, Söderholm and Berglund (2009) analyse the determinants of recycling efforts among 2800 Swedish households using statistical analyses (probit regression) based on stated preference surveys. The findings indicate that both economic and moral motives influenced the household' waste handling behaviour and recycling rates. To conclude, both studies found factors that contributes to increase recycling activities are; the willingness to contribute to a better environment (an environmental public good), the feeling of moral obligation for recycling and the beliefs about others' waste sorting behaviour.

2.2.1 The importance of external conditions for an increased waste sorting effort

Some previous studies have focused on the importance of external conditions for waste sorting behaviour and recycling outcomes (Best & Kneip, 2011; Dahlén et al, 2007; Hage

& Söderholm, 2008; Mattsson et al, 2003; Ölander & Thogersen, 2005). The external conditions can be seen as the collection infrastructure facilitating recycling in terms of accessibility. Examples of external conditions are distance to, and the number of, recycling stations close to home and whether curbside recycling for waste sorting is provided. These studies highlight the importance of a low opportunity cost regarding waste sorting activities. However, these previous studies have estimated the effect on the amount of collected waste and not on the waste sorting degree.

Dahlén et al (2007), examines six municipalities in southern Sweden with similar socio-economic conditions, but with different collection systems: waste sorting through drop-off stations and curbside recycling. The findings show that more metal, plastic and paper packaging was recycled with curbside collection compared to drop-off recycling. When separate collection for food waste was included in the curbside system, the overall waste sorting of packaging waste increased. In the study, 26 waste component analyses of residual waste carries out in Swedish municipalities during 1998 to 2004 were evaluated. Multivariate data was applied. However, the transition from drop-off recycling to curbside recycling was not examined. Though, changes in waste sorting behaviour when going from drop-off recycling to curbside recycling of packaging waste has been studied in Germany, by Best and Kneip (2011). They found that participation in recycling activities increased with approximately 19 percent after the transition to curbside recycling. The study was conducted using pre- and post-treatment surveys and applies conditional fixed-effects regression models. They used data from a natural experiment on recycling participation between 2006 and 2008 (N=1882). Furthermore, Mattson, Berg, and Clarkson (2003) made a case study analysis of different collection system for recyclables in Sweden and England. The study highlights the importance of a transparent collection system in terms of simplicity and design for increased waste sorting. Hence, how easy the collection system is to understand and manage will have a significant effect on the collection rates of recyclables, by facilitating waste sorting.

Although curbside collection of household waste has received previous attention as a policy instrument important for recycling outcomes, the effect of different waste sorting systems have received far less attention. However, in a survey conducted by the Swedish Waste Management Association (SWMA) in 2016, it was found that waste sorting behaviour was affected by the collection system used (SWMA, 2016b). In the study, 246 waste component analyses of residual waste carried out in Swedish municipalities during 2013 to 2016 was evaluated. Compared to single-family houses sorting packaging waste at drop-off stations, a larger fraction of packaging and newspaper waste was sorted out in single-family houses using either four-compartment bins or different coloured bags for waste sorting, which is in line with findings in previous studies made. Furthermore, households using four-compartment bins had a lower quantity of residual waste (4 kg) compared to households using different coloured bags (6 kg), indicating better waste sorting with multi-compartment bins. However, the system of bags and containers was not examined, and no econometric analysis was made. Hence, regional differences that are assumed to affect waste sorting behaviour among households were not included.

3 Theoretical framework

There are several theoretical explanations to why an individual chose to comply with environmental regulations under producer ordinance. Households waste sorting behaviour can be explained through, economic, normative and social motives. In the following section a theoretical framework is presented which can be used to understand recycling behaviour among Swedish households. The conceptual framework of this study follows Brekke, Kverndokk and Nyborg (2003) who provides a framework in which the relationship between moral motivation, economic incentives, public policy and the choice of individuals' waste sorting effort can be explained.

3.1 Economic and behavioural motives for waste sorting

Rational choice theory explains human behaviour as a result of choice among alternatives. Individuals will choose the alternative that optimally satisfies their preferences (Best & Kneip, 2011; Lindhal, 2015). Hence, the choice to recycle is a decision based on weighing trade-offs between various options. According to rational choice theory, individuals will engage in waste separation if the expected utility of doing so exceed the utility of simply throwing recyclables in the garbage bin together with non-recyclable waste (Best & Kneip, 2011). The individual will thus choose the option (sorting waste or not) with the highest net benefit.

Since households contribute to an improved environmental quality when recycling waste, Brekke, Kverndokk and Nyborg (2003) suggest that their actions can be seen as a contribution to the public good. The public good is characterized by non-rivalry and non-excludable. Moreover, since households do not receive any penalty when not sorting packaging waste and newspaper, the action of waste sorting can be seen as a voluntary action. Economic theory predicts that voluntary contributions to the public good will be limited if the net benefit (payoff) are higher for each individual when not contributing to the public good, compared to if they do (Berglung et al, 2010). From this follows that voluntary waste sorting of recyclables are assumed to be low due to free-riding problem. This because households are expected to promote the public good without receiving economic compensation for their engagement in waste separation.

Previous studies have found that recycling activities is associated with a relatively high time cost (Bruvoll, Halvorsen & Nyborg, 2002). Following Brekke, Kverndokk and Nyborg (2003), each individual will allocate a fixed amount of leisure time between 'recycling activities' and 'other activities'. Hence, to participate in recycling activities involves an opportunity cost of time since leisure time must be devoted to recycling.[2] A transition from drop-off recycling to curbside recycling will lower the cost of recycling in terms of time and effort and should therefore lead to a better waste sorting behaviour among households. Even if drop-off recycling and curbside recycling provides the same desired outcome with less packaging waste in the waste bin, the behavioural cost in terms of time, effort and storage cost will differ between the two. Inspired by Brekke, Kverndokk and Nyborg (2003), Hage, Söderholm and Berglund (2009) illustrates behaviour motives for waste sorting through the following economic model, where *x* is the waste sorting effort:

$$p = S(x, Z) + b(x) - T(x)$$

The payoff (p) individuals receives from sorting waste is a function of self-image (S), to which extent waste sorting generates public goods (b) and the opportunity cost (T) associated to it. Z represents a vector of variables influencing the self-image; the feeling of moral obligation, the beliefs about others' waste sorting behaviour, and the perceived positive externalities arising from waste sorting. Individuals will maximize the payoff received from waste sorting when: $S'(x) + b'(x) = T'(x)$. *S*, *b* and *T* are increasing with waste sorting effort, and are assumed to be zero if no waste sorting is undertaken. Also, $S''<0$, $b''<0$ and $T''>0$. Furthermore, the voluntary contribution to public goods is assumed to be low due to the free-riding problem. From this follows that the main determinates for individuals waste sorting behaviour are factors influencing an individual's self-image as a responsible person and the opportunity cost for recycling. However, the importance of factors influencing the self-image will become less important when collection systems

[2] There will be a choice of spending more time on leisure or spending more time contributing to the public good. Each individual face a time constraint corresponding to: $l_i + e_i = T$. T is total time, e_i is effort spent on contributing to the public good (measured in units of time) and l_i is leisure (Brekke, Kverndokk & Nyborg, 2003).

makes it easier for households to sort waste (Hage, Söderholm & Berglund, 2009). Hence, when the opportunity cost to recycle becomes lower.

3.1.1 The importance of a low opportunity cost for waste sorting activities

The importance of a low opportunity-cost for waste sorting activities is illustrated in the ABC hypothesis, a model integrating moral attitudes, norm-based behaviour and external conditions to waste sorting engagement (Ölander & Thogersen, 2005). The model hypothesizes a marginal improvement in one of these three, and how that improvement affects participation in recycling activities. External conditions can be understood as the collection infrastructure making recycling possible, hence, the number of drop-off stations and collection bins and the distance/accessibility to them. If the external conditions make it very easy to recycle (opportunity-cost is low), the model predicts that almost all individuals will do so. Hence, environmental concern and moral attitudes toward recycling will not be an important determinant for recycling outcomes. At the same time, if the external conditions make it very hard to recycle (opportunity-cost is high), few people will engage in recycling regardless of their environmental concerns and moral attitudes towards recycling. The ABC-model predicts that a marginal improvement in the external condition will have a larger effect on recycling outcomes compared to a marginal increase in moral attitudes (Ölander & Thogersen, 2005). Hence, the opportunity cost associated with waste sorting will determine the waste sorting degree, which makes municipal policy instrument that facilitates recycling in the context of daily life important in order to stimulate waste sorting among households. This can be done by improved collection infrastructure with better accessibility to recycling facilities, which curbside recycling of packaging waste provides.

Relating the above reasoning to waste management policy instrument used in Swedish municipalities, both curbside recycling programs and weight-based collection fees will affect the opportunity cost of waste sorting and provide incentives for reduction of waste, but doing so in different ways. Curbside recycling reduces a household’s cost of recycling by making recycling less time consuming, which will affect the opportunity cost in terms of time and effort. A weight-based collection fee, on the other hand, increases a household’s cost of throwing additional packaging waste in the waste bin, relative to the cost to recycle the waste at the recycling station, since not recycling leads to a higher waste collection fee. The opportunity cost to recycle at the drop-off stations is lower compared to throwing additional waste in the bin and paying a higher weight collection fee (Jenkins et al, 2003). Hence, a weight-based collection fee will also affect the opportunity cost of waste sorting, but not in terms of time. Furthermore, weight-based collection fees are assumed to give an indirect incentive to recycle. The direct effect is to reduce the waste quantity, which in turn can create indirect incentives for households to buy less packaged products (Best & Kneip, 2011).

However, the different curbside collection systems used among municipalities require the households to sort their waste in different ways. A curbside collection system that lower the opportunity cost of recycling by facilitating waste sorting in everyday life are therefore assumed to increase the amount of recyclables and lead to a better waste sorting behaviour. Since simplicity and design of waste system will have an impact on the recycling rates (Mattson, Berg & Clarkson, 2003), one can assume that the different curbside collection systems used potentially differ in terms of opportunity cost. A waste sorting system that is easy to manage will generate higher collection rates of recyclables.

4 Data

In the following section the data used in the analysis are presented. Descriptive statistics of included variables are presented in table 1. A detailed variable description with expected signs on the sorting degree are presented in table 8 in Appendix A.

4.1 Presentation of data

To meet the aim of this thesis and to answer the thesis research question, data from the Swedish Waste Management Association (SWMA), Kolada, Statistics Sweden (SCB), the Swedish Association of Local Authorities and Regions (SKL) and from a study conducted by Ek and Miliute-Plepiene (2016) are used. Kolada is a database containing statistics for Swedish municipalities, mainly based on data from Statistics Sweden. The Swedish Waste Management Association is a branch organisation for waste management and recycling. The organisation compiles waste-related data through the database Avfall Web [Waste Web]. Through this web platform the municipalities themselves report data about waste collection and recycling annually. Municipalities are asked to answer about 100 questions. Avfall Web provides information on the total amount of packaging waste, residual waste and food waste collected in tonnes from households in a municipality in a given year. Households can sort residual waste and food waste in separate fractions or throw them together as a mixed fraction in the same waste bag. In Avfall Web, the total amount of residual waste and food waste is reported together as waste in “bins and bags”, regardless on which waste sorting system being used. However, Avfall Web also provides information on collected amounts of food waste going to biological recycling (composted, digested and threatened at sewage plants). By summing these into a single measure the total amount of separated food waste collected for each municipality is obtained. These three variables regarding waste collection are compounded into a variable capturing the waste sorting effort.

The households’ waste sorting effort is measured by a variable capturing the sorting degree in a municipality in a given year. The dependent variable measures the proportion of separated waste from the total amount of household waste collected (kilogram per capita per year). The variable will take a value between one and zero. A value of one indicates that all household waste has been sorted and a value of zero indicates the opposite.

$$y_{it} = \frac{\text{Sorted waste}_{it}}{\text{Total waste}_{it}} = \frac{\text{Food waste}_{\text{it}} + \text{Recyclables}_{\text{it}}}{\text{Food waste and residual waste}_{it} + \text{Recyclables}_{it}}$$

All variables are reported in tonnes per year and have been converted to kilograms per capita per year for each municipality. The total amount of household waste is obtained by summing collected quantity recyclables (packaging waste and newspaper) with collected quantity of waste in bins and bags. The amount sorted household waste is obtained by summing collected quantity recyclables with food waste collected for biological treatment. Home composting of food waste is not included in Avfall Web (SWMA, 2016c).

Information regarding which curbside recycling system provided for residents living in single-family houses are obtained from Ek and Miliute-Plepiene (2016). Only municipalities that collect more than one fraction of packaging waste are included in their study. The different collection systems presented are grouped into three categories in this study. A collection system that contains either bags, bags and crates, or bags- buckets- and containers, are in this study compounded into one group corresponding to the so called first generation of curbside collection systems. The other two systems are waste sorting through two four-compartment bins or different coloured bags (usually called optical sorting). [3] Not one of the included municipality provides more than one collection system for waste sorting, and not one of the included municipalities changed the waste sorting system used during the period between 2007 and 2015. Ek and Miliute-Plepiene also provide information on the participation rate in curbside collection among single-family houses, and whether the collection system is implemented as a trial or not. The participation rate vary from 1 to 100 percent between the municipalities.

[3] The three different systems are described in SWMA (2014).

The choice of control variables in this study are obtained from several sources and captures residential structure, socio-economic differences and environmental preferences. From Kolada municipal data on population, mean age, education level, unemployment rate, and share of foreign-borne outside EU/EFTA are obtained. From SCB municipal data on average income (in SEK ‘000), population density and share of voters on the Green Party [Miljöpartiet] in national elections are obtained. From SKL data over political majority in the local government is obtained. The share of single-family houses, number of recycling stations and whether a weight-based collection fees is used are obtained from Avfall Web. Information on whether collection of food waste is provided is obtained from the Swedish Waste Management Association (2016a). Introduction year for collection of food waste are missing for 29 municipalities. After contact with municipalities I received the introduction year for 25 of them.

4.1.1 Limitations in data

The reliability of self-reported data is limited and incorrect information concerning waste collection can occur when using data from Avfall Web (SWMA, 2016c). Furthermore, in the period between 2007 and 2015 Avfall Web compiles disaggregated data for 264 out of 290 municipalities. Municipalities that co-manage their waste collection reports aggregated data to Avfall Web and are not included in this study. [4] Since not all Swedish municipalities report data to Avfall Web and some questions regarding waste management are left unanswered by the municipalities’, only data from a sample of municipalities are used in the analysis. However, the number of observations in Avfall Web rises over time. Since the selection is not random it could be systematic differences between municipalities included in the analysis and municipalities that are not. Sample selection bias refers to the problem when the dependent variable is observed only for a restricted, non-random sample, which leads to bias and inconsistency of the OLS estimator (Stock & Watson, 2011).

4.2 Descriptive statistics of included variables

Data regarding waste management and control variables are compounded to an unbalanced panel containing 264 Swedish municipalities for the period 2007 to 2015. Descriptive statistics of included variables in the analysis are presented in table 1. As can be seen, there are missing observations among variables obtained from Avfall Web.

Table 1: *Descriptive statistics of included variables, 2007-2015 (N=264)*

VARIABLE	Obs	Mean	Std. Dev.	Min	Max
Dependent variable					
Waste sorting degree	1 341	0.35	0.13	0.08	0.71
Type of household waste collected (kg/capita)					
Total waste (bins & bags + recyclables)	1 818	304.22	65.60	114.14	807.30
Sorted waste (food waste + recyclables)	1 342	102.80	38.10	16.19	224.08
Waste in bins and bags	1 938	227.14	57.96	41.13	700.57
Food waste	1 386	25.18	27.18	0.00	122.19
Recyclables; Packages and newspaper	1 861	77.28	23.15	0.01	213.68

[4] AÖS: Avfallshantering Östra Skaraborg (Falköping, Hjo, Karlsborg, Skara, Skövde, Tibro, Töreboda), Gästrike Återvinnare (Gävle, Hofors, Ockelbo, Sandviken, Älvkarleby), KSRR (Kalmar, Mörbylånga, Nybro, Oskarshamn, Torsås), LSR; Landskrona-Svalövs Ren-hållnings AB (Landskrona, Svalöv), Motala/Vadstena renhållningsnämnd (Motala, Vadstena), Västra Mälardalens kommunalförbund (Arboga, Köping, Kungsör) Södertälje including Nykvarn (SWMA, 2016c).

Policy variable (independent variable)					
Binary treatment variable (dummy)					
Curbside collection	2 376	0.13	0.33	0	1
Four-compartment bins	2 376	0.08	0.26	0	1
Different coloured bags	2 376	0.003	0.05	0	1
Bags and containers	2 376	0.05	0.21	0	1
Continous treatment variable (participation rate)					
Curbside collection	2 376	0.06	0.21	0.00	1.00
Four-compartment bins	2 376	0.04	0.17	0.00	0.95
Different coloured bags	2 376	0.003	0.05	0.00	0.99
Bags and containers	2 376	0.02	0.12	0.00	1.00
Additional policy variable					
Weight-based collection fee (dummy)	2 376	0.11	0.31	0	1
Collection of food waste (dummy)	2 340	0.42	0.50	0	1
Recycling stations (number/capita)	1 839	0.0008	0.0006	0	0.004
Environmental preferences					
Green Party in local government (dummy)	2 376	0.29	0.45	0	1
Share of Green Party voters	2 376	4.82	1.91	0.80	12.80
Socio-economic/ demographic variables					
Population	2 376	33 419.87	68 603.73	2 421	923516
Population density	2 376	147.90	508.30	0.20	5 307.6
Age (average)	2 376	43.02	2.62	36.10	49.6
Income (average, SEK ’000)	2 376	270.59	38.97	204.70	590.8
Share of foreign-born (outside EU/EFTA)	2 376	5.86	3.79	0.90	29.4
Education level	2 376	30.82	9.82	16.40	74.5
Unemployment rate	2 376	6.30	2.44	1.10	17.2
Share of single family houses	1 789	0.60	0.16	0.01	0.99

Curbside collection of packaging- and newspaper waste implemented to facilitate waste sorting among single-family houses is provided in 13 percent of the cases. A weight-based collection fee used to provide economic incentives for an increased waste sorting effort, is used in 11 percent of the cases. Collection of food waste, not a part of an integrated waste sorting system, is provided in 42 percent of the cases and the most common policy instrument used to increase households waste sorting effort.

The number of included municipalities that provide curbside recycling for resident living in single-family houses increases from 21 in 2007 to 44 in 2015. Two municipalities end with curbside collection in the year of 2014. The participation rate in curbside recycling schemes among households living in single-family houses. On average 6 percent of households living in single-family houses are provided with curbside recycling. A graphical presentation over which waste sorting system used is presented in figure 1. As can be seen, the most common way to separate household waste is into two four-compartment bins followed by waste sorting into different types of bags and containers. Only two municipalities in the data offers waste sorting through different coloured bags. Moreover, 27 of the included municipalities starts with curbside collection of packaging waste and newspaper during the period 2007-2015, hence makes a transition from drop-off recycling to curbside recycling for single-family houses.

The waste sorting degree among the included municipalities is on average 0.35. This means that 65 percent of the collected household waste consist of waste that could have been sorted, hence, a mixture of residual waste, food waste and packaging waste and newspaper intended for material- and biological recycling. A graphical presentation of the sorting degree is presented as a scatterplot in figure 2. As can be seen, the number of observations increases over time. Only eight observations for the waste sorting degree are available for 2007. Furthermore, the average waste sorting degree is higher in 2008 and 2009 due to increased amount of collected food waste. The average waste sorting degree during these two years are estimated from 25 respectively 27 observations. Since the dependent variable are observed from a restricted sample there is a risk for sample selection bias.

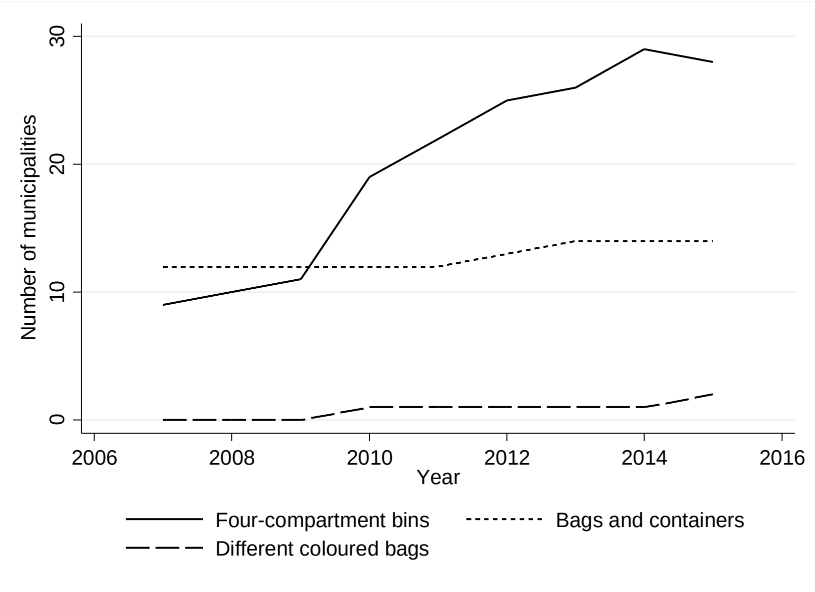

Figure 1: *Different curbside collection system used for waste sorting.*

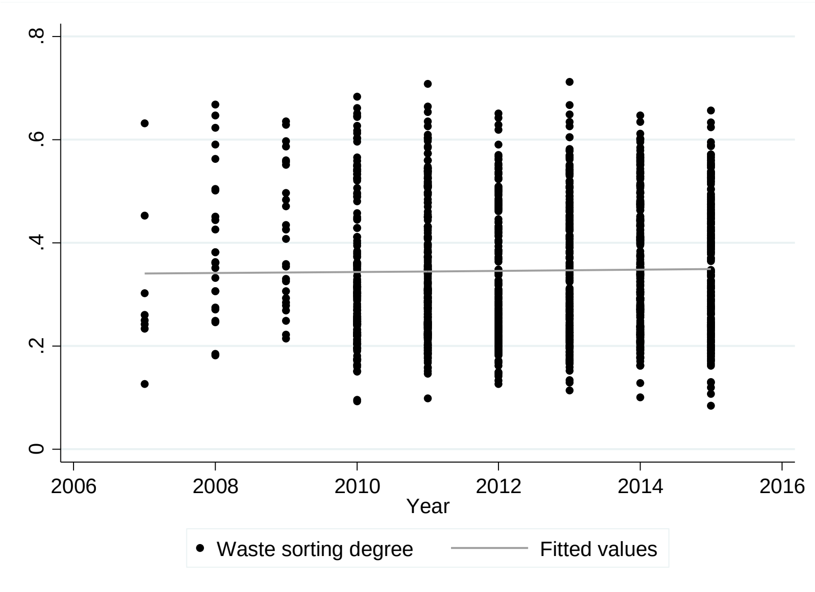

Figure 2: *Waste sorting degree over time.*

5 Method

In all empirical analyses at least three potential threats to the internal validity can occur; errors in the data material used, non-representative sample, or wrongly specified regression models (Stock & Watson, 2011). In the following section a number of methodological challenges are described and the empirical strategies used to overcome them. Furthermore, the regression models are presented.

5.1 Choice of method

In order to estimate the effect of a transition from drop-off recycling to curbside recycling on the waste sorting effort, regression models with a difference-in-difference (DID) design are used. The DID approach compares the change in waste sorting degree before and after the introduction of curbside collection in a municipality, to changes in waste sorting among municipalities that never implement curbside collection of packaging waste, hence, a control group. The control group consists of municipalities in which households recycle packaging waste at a recycling stations. When comparing changes between the two groups (treated and control), observed and unobserved municipality characteristic that might be correlated with sorting degree and curbside schemes can be controlled for, and the treatment will be as if randomly assigned (Stock & Watson, 2011). The DID estimator is, hence, the average change in waste sorting degree among municipalities that makes a transition to a new recycling system, minus the average change in sorting degree among municipalities without curbside collection (Stock & Watson, 2011). A key assumption in DID models is the parallel-trend assumption that states that the average change in outcome in the control group represents the counterfactual change in the treatment group if there were no treatment (Galiani, Gertler & Schargrodsky, 2005). Hence, changes in waste sorting degree among municipalities with no curbside recycling is assumed to be an estimate of the true counterfactual effect.

5.1.1 Fixed-effect regression models

A concern arising is that municipalities that choose to implement curbside recycling differ from municipalities that choose not to. Omitted variable bias (OVB) occur if these differences are correlated with the waste sorting behaviour among households' but are omitted from the empirical model. This causes the correlation between curbside recycling schemes and waste sorting efforts to be either under- or overestimated. One way to control for time-invariant unobserved variables in panel data is to use fixed effect regression models (Stock & Watson, 2011) which have been used in previous studies (Andersson & Stage, 2017; Ek & Miliute-Plepiene 2016).

Municipality fixed effect are included in the regression models to capture potential OVB from variables that vary across municipalities but are constant over time (Stock & Watson, 2011). For example, regional differences in budget spent on waste management (to implement curbside collection, as well as the different waste sorting systems are associated with different costs) and differences in how to interpret the producer ordinance, assuming these do not change over time. Time fixed effects on the other hand are included to capture potential OVB from variables that vary over time but are constant across municipalities. Therefore, variables are assumed to influence the waste sorting behaviour in the same way across all municipalities. For example; legislation concerning waste management at a national or EU level or changes in attitudes toward environmental issues in the society. Fixed effect regression models cannot, however, control for omitted variables that vary both over time and across municipalities. For this control variables are used.

5.1.2 Control variables

Previous studies have shown that variation in waste sorting effort are affected by policy instruments, socio-economic characteristics and environmental preferences among households (Best & Kneip, 2011; Dahlén et al, 2007; Hage & Söderholm, 2008). Control variables for region-specific characteristics must therefore be used in the regression models to obtain reliable estimates of the causal effect of waste sorting systems. In this study control variables are included to characterize residential structure as the share of single-family houses living in urban/rural areas, socio-economic differences as education level, average income and amount of foreign borns. The share of voters at the Green party [Miljöpartiet] in national elections is included as a proxy variable for environmental preference among households. Whether the Green Party is represented in the local government is included as a proxy variable for environmental preference among municipalities.[5] Three additional variables are included to control for waste-reduction policy instruments assumed to have a direct effect on waste sorting effort (Andersson & Stage, 2017; Best & Kneip, 2011; Dahlén et al, 2006; Ek & Miliute-Plepiene 2016). These three variables are: the use of economic incentives in form of weight-based collection fee, whether collection of food waste is provided and the accessibility to recycling stations as well as the number of recycling stations per capita. To overcome the problems with potentially bad control variables, this study only controls for collection of food waste in municipalities where the waste system used does not provide an integrated solutions for both packaging waste and food waste. A definition of the included control variables and their expected effect on households waste sorting degree are presented in table 8, in Appendix A.

5.1.3 Endogeneity

Potential endogeneity problems occurs if the choice to implement curbside recycling in municipality *i* in year *t* are a result of the sorting degree among the household in the same year. Hence, the independent variable is in itself an outcome of the dependent variable. This is called reverse causality and will lead to a wrongly estimated error term. A strategy to overcome this problem is to include lagged values for curbside recycling schemes. This is motivated by the fact that households' waste sorting behaviour is likely to affect future policy implementation, but it is not possible that waste sorting behaviour today can affect policy implementations made in previous periods. Only lagged values for three periods are included in the regression models to avoid problems with multicollinearity. To include lagged values for more periods would also decrease the number of observations.

5.1.4 Autocorrelation

Autocorrelation is a common problem in panel data where the value of a variable in period *t* almost per definition depends on the value in the previous period (*t-1*). This causes underestimated standard errors which can give rise to wrongly significant results. To overcome the problem with wrongly significant results clustered standard errors that are robust to heteroscedasticity and autocorrelation are used in the regression models. A Wooldridge's test for autocorrelation in panel-data models are therefore performed, showing that autocorrelation occurs in the data. Clustered standard errors allows observations for each entity (municipality) to be correlated over time (Stock & Watson, 2011).

5.2 Empirical models

The first model estimates the effect of curbside collection on waste sorting degree. Each observation are defined as a municipality *i* in a given year *t*.

$$y_{it} = \beta x_{it} + \beta C_{it} + \ a_i + \lambda_t \ + u_{it} \tag{1}$$

[5] The decision to implement curbside recycling is made by the local government. Hence, one could expect that local governments with high environmental preference is more willing to implement municipal policies aimed to increase waste sorting behaviour among households.

The dependent variable y_{it} is the sorting degree in municipality *i* in year *t*. The dependent variable will take a value between one and zero. x_{it} is a binary treatment variable, hence, a dummy that takes the value of one if municipality *i* offers curbside recycling in year *t* and zero otherwise. C_{it} is a vector controlling for region-specific characteristics expected to affect the waste sorting behaviour among households. These control variables are included in the regression models to empirically isolate the effect of curbside recycling on the waste sorting degree. a_i is municipality fixed effects and λ_t is time fixed effects, controlling for unobserved factors varying across municipalities and time. u_{it} is an error term including changeable and non-observed factors that are expected to effect the waste sorting degree.

Since the participation rate in curbside recycling schemes vary widely between municipalities, a slightly modified version of model (1) is estimated. In regression (2) the dummy variable for curbside recycling are excluded and the share of single-family households participating in curbside recycling in municipality *i* in year *t* are included. z_{it} is, hence, a continuous treatment variable. Even if the participation rate is assumed to increase over time (Ek & Miliute-Plepiene, 2016), a constant participation rate for municipality *i* is used. However, if a municipality introduce curbside collection as a trial and then extend it to involve a higher share, this will be captured, since data for this is available.

$$y_{it} = \beta z_{it} + \beta C_{it} + a_i + \lambda_t + u_{it} \quad (2)$$

Since this thesis aims to estimate the effect of different curbside collection systems used for waste sorting, a modified version of regression model (1) is estimated. Hence, in regression (3) three dummy variables are included that correspond to waste sorting either through four-compartment bins, different coloured bags, or bags and containers. The individual dummy variable takes the value of one if municipality *i* offers curbside recycling through one of these systems in year *t* and zero otherwise. Additionally, a regression model is estimated including the participation rate in curbside recycling among single-family households, instead of the three dummy variables.

$$y_{it} = \beta a_{it} + \beta b_{it} + \beta d_{it} + \beta C_{it} + a_i + \lambda_t + u_{it} \quad (3)$$

5.2.1 Estimated treatment effect over time

It is possible that a delay occur between implementation of curbside recycling and when the full effect on households' waste sorting behaviour is achieved. Therefore, a modified version on equation (1) and (3) are estimated with lagged values of the binary treatment variable one, two and three years. Lagged values of the independent variable have been used in previous studies to estimate the effect of municipal policy on waste sorting behaviour over time (Andersson & Stage, 2017; Ek & Miliute-Plepiene, 2016), and can also solve potential problems with reverse causality. Furthermore, to check for certain types of endogeneity problems in the model lead values of the binary variable for one and two years are included. The model will suffer from endogeneity problems if significant coefficients are estimated before introduction of curbside recycling. This means that the results are potentially driven by factors not included in the regression models. To include lead and lagged values for additional time periods would decrease the number of observations.

$$y_{it} = \beta x_{it+2} + \beta x_{it+1} + \beta x_{it} + \beta x_{it-1} + \beta x_{it-2} + \beta x_{it-3} + \beta C_{it} + a_i + \lambda_t + u_{it} \quad (4)$$

5.3 Testing the parallel-trend assumption

A concern arising is that municipalities that chose to implement curbside recycling differ from municipalities that choose not to. By testing the secular time trends between the two groups before and after curbside collection was introduced (before transition from drop-off recycling to curbside recycling), it is possible to find out if they do. The secular time trends have been tested in previous studies in order to compare treated municipalities with a control group (Galiani, Gertler & Schargrodsky, 2005).

To test if the two groups are different in any respect, separate year dummies are made for the control group and to (eventual) treated municipalities. The year dummies are included in a modified version of regression model (1), where the dummy variable corresponding to curbside recycling are replaced with 18 year dummies. Additionally, an F-test is made to test if the year dummies for the two groups are the same in pre-treatment periods. Year dummies for the treated municipalities are only tested in their pre-treatment period with year dummies for the control group. However, the result show a p-value below 0.05, which indicates that there is a difference in trend between municipalities that choose to implement curbside collection and municipalities choosing not to when controlling for background variables and fixed effects for entity and time. Since the empirical model used in this study are assuming two groups with identical time trends, the estimated results must be interpreted with caution.

6 Results

Results from the regression models are presented in the following section. The individual coefficient is statistically significant at the 10, 5 or 1 percent significance level. Standard errors are given in parenthesis. The number of municipalities included in the regression models decreases when additional control variables are included. This is because control variables are missing for some of the included municipalities.

6.1 Expected results

Since households are relieved from their responsibility to transport packaging waste and newspaper to assigned drop-of stations when curbside recycling is provided, less time are taken from leisure activities to recycling activities, which are assumed to increase the waste sorting effort. Hence, when curbside recycling is provided for residents living in single-family houses in Swedish municipalities the estimated coefficients are assumed to be positive. The estimated treatment effect over time are assumed to increase, partly because it may take time to learn a new sorting system, but also due to slow policy implementation. This because implementation are assumed to increase gradually. Furthermore, the marginal effect on the waste sorting degree associated with an increase in the participation rate among resident living in single-family houses are assumed to be positive.

6.2 The estimated effect of curbside collection of packaging waste and newspaper

The estimated effect of introducing curbside collection of packaging waste and newspaper for residents living in single-family houses on the average waste sorting degree in a municipality is presented in table 2. Columns 1-3 present regression models with a binary treatment variable and columns 4-6 present regression models with a continuous treatment variable. Positive but not statistically significant coefficients are estimated when a binary treatment variable is used. This result is contrary to previous studies, in which a significant effect on the waste sorting behaviour has been found when residential curbside recycling programs are implemented (Best & Kneip, 2011; Dahlén et al 2007; Hage & Söderholm, 2008). However, previous studies have estimated the effect on the amount of collected packaging waste and not on the sorting degree. When a continuous treatment variable is used positive and significant coefficients at a 1 percent level are estimated, as expected. The estimated coefficient is 0.180 when additional control variables are included in column (6). This means that the average sorting degree in a municipality increases with

0.0018 percent when the participation rate among residents living in single-family houses increase with one percent.

The coefficient for weight-based collection fee and food waste collection is positive and significant, which indicates that the two additional policy instruments have a positive effect on waste sorting degree among residents. The coefficient for the number of recycling stations per capita is positive but not significant. Furthermore, the value of R^2 increases when additional control variables are included which indicates that region-specific characteristics and additional policy variables do captures some of the variation in the outcome. Even if the proportion of explained variation increases, nothing can be said by R^2 about the causal effect of the included variables. R^2 is the fraction of the sample variance of the dependent variable explained by the regressor (Stock & Watson, 2011).

Table 2: *Estimated effect of curbside collection on waste sorting degree*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Curbside coll. (binary)	0.0324	0.0255	0.0468			
	(0.0270)	(0.0361)	(0.0424)			
Curbside coll. (continuous)				0.140***	0.135***	0.180***
				(0.0398)	(0.0385)	(0.0503)
Weight-based coll. fee			0.0266**			0.0262**
			(0.0114)			(0.0105)
Food waste collection			0.0321*			0.0454***
			(0.0165)			(0.0137)
Drop-off stations /capita			0.333			4.988
			(17.50)			(15.43)
Intercept	0.282***	0.143	0.278	0.286***	-0.0723	0.141
	(0.0342)	(0.638)	(0.589)	(0.0244)	(0.611)	(0.536)
Additional controls	No	Yes	Yes	No	Yes	Yes
Observations	1,341	1,259	1,225	1,341	1,259	1,225
R-squared (within)	0.055	0.083	0.103	0.094	0.122	0.162
Number of municipalities	260	254	247	260	254	247

Clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Fixed effect for time (year) and entity (municipality) are included. Included control variables: population, population density, mean age, mean income, share of single-family households, education level, unemployment rate, share of foreign-born outside EU/EFTA, share of Green party voters in national election, Green party represented in local government.

6.3 The estimated effect of different waste sorting systems used

The estimated effect of different waste soring systems are presented in table 3. As before, columns 1-3 present regression models with a binary treatment variable and columns 4-6 present regression models with a continuous treatment variable. When a binary treatment variable is used positive and significant coefficients are estimated for waste sorting with different coloured bags. The estimated coefficient is 0.216 when additional control variables are included in column (3). This means that the average waste sorting degree in a municipality increase with 21.6 percent after a transition from drop-off recycling to curbside recycling using different coloured bags for waste sorting. However, the results are driven by only two municipalities included in the data. One explanation to why such large effect are observed can be that 99 percent of all the residents living in single-family houses are participating in curbside recycling in these two municipalities. The estimated effect of waste sorting through four-compartment bins is positive but not significant when additional control variables are in included in column (3). The estimated effect on waste sorting degree using bags and containers is negative but not significant when additional control variables are in included in column (2) and (3). Once more, the value of R^2 increases with additional control variables.

When a continuous treatment variable is used, positive and significant coefficients at a 1 percent level are estimated for waste sorting through four-compartment bins and different coloured bags, as expected. For four-compartment bins, the estimated coefficient is 0.163 when additional control variables are included in column (6). This means that the average sorting degree in a municipality increase with 0.00163 percent when the participation rate among resident living in single-family houses increase with one percent. For different coloured bags, the estimated coefficient is 0.267 when additional control variables are included in column (6). This means that the average sorting degree in a municipality increase with 0.00267 percent when the participation rate among resident living in single-family houses increase with one percent. Negative but not significant coefficient for waste sorting through bags and containers are estimated in column (5) and (6).

Table 3: *Estimated effect of different recycling systems on waste sorting degree*

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Four-compartment (binary)	0.00576	-0.0175	0.00897			
	(0.0202)	(0.0361)	(0.0503)			
Coloured bags (binary)	0.182**	0.184***	0.216***			
	(0.0789)	(0.0685)	(0.0818)			
Bags and containers (binary)	0.00762	-0.00227	-1.81e-05			
	(0.0173)	(0.0184)	(0.0180)			
Four-compartment (cont.)				0.116***	0.108***	0.163***
				(0.0243)	(0.0260)	(0.0485)
Coloured bags (cont.)				0.218***	0.218***	0.267***
				(0.0558)	(0.0481)	(0.0599)
Bags and containers (cont.)				0.00170	-0.0127	-0.0162
				(0.00496)	(0.0122)	(0.0117)
Weight-based coll. fee			0.0271**			0.0267**
			(0.0107)			(0.0104)
Food-waste collection			0.0360**			0.0480***
			(0.0161)			(0.0136)
Drop-off stations /capita			0.622			4.872
			(17.51)			(15.48)
Intercept	0.299***	0.222	0.379	0.297***	-0.0382	0.182
	(0.0198)	(0.619)	(0.568)	(0.0185)	(0.609)	(0.532)
Additional controls	No	Yes	Yes	No	Yes	Yes
Observations	1,341	1,259	1,225	1,341	1,259	1,225
R-squared (within)	0.080	0.113	0.137	0.104	0.133	0.177
Number of municipalities	260	254	247	260	254	247

Clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Fixed effect for time (year) and entity (municipality) are included. Included control variables: population, population density, mean age, mean income, share of single-family households, education level, unemployment rate, share of foreign-born outside EU/EFTA, share of Green party voters in national election, Green party represented in local government.

6.4 Estimated treatment effect over time

6.4.1 Curbside collection of packaging waste and newspaper

The estimated effect on waste sorting degree before, during and after introduction of curbside recycling is presented in table 4. The coefficient captures the effect one, two and three years or more after introduction of curbside recycling. Coefficients one and two years before introduction are included to examine if the model suffers from endogeneity problem.

A graphical illustration of the result corresponding to column (3) is presented in figure 3 in Appendix B. One municipality that introduce curbside recycling under the given time period ends with curbside collection before 2015. This municipality is therefore excluded from the analysis.

Positive and significant coefficient are estimated before, during and after introduction of curbside recycling when control variables are included in column (2) and (3). Since positive and significant pre-treatment effect are observed, problems with endogeneity in the model are revealed. This indicate that municipalities that later on introduce curbside recycling for residents living in single-family houses tend to sort their waste better before the transition. The treatment estimates are therefore confounded and the effect on the sorting degree among municipalities are most likely driven by factors not included in the model. Furthermore, the estimated effect is slightly higher one year before introduction of curbside collection.

Introduction of residential curbside recycling for single-family houses in year *t* is associated with a marginal increase in the waste sorting degree with 11 percent in a municipality, when additional control variable are included in column (3). The coefficient is significant at a 1 percent level. The marginal increase in waste sorting degree one year after introduction is 13.2 percent and 12.7 percent two years after. The coefficient are significant at a 1 percent respectively 5 percent level. The long run effect corresponds to an increase in waste sorting degree with 14.2 percent. Since the implementation of curbside recycling are assumed to increase gradually, the results was somewhat expected.

Table 4: *Estimated treatment effect over time; curbside collection of waste*

VARIABLE	(1)	(2)	(3)
2 years prior	0.0172	0.0512***	0.0499***
	(0.0203)	(0.0175)	(0.0182)
1 year prior	0.0765***	0.107***	0.111***
	(0.0264)	(0.0318)	(0.0379)
Immediate effect	0.0653**	0.0914**	0.110***
	(0.0329)	(0.0381)	(0.0423)
1 year after	0.0850***	0.109***	0.132***
	(0.0296)	(0.0357)	(0.0371)
2 years after	0.0705*	0.0951*	0.127**
	(0.0395)	(0.0484)	(0.0543)
3 years after	0.0839*	0.102*	0.142**
	(0.0438)	(0.0520)	(0.0575)
Weight-based coll. fee			0.0271**
			(0.0112)
Food-waste collection			0.0366**
			(0.0157)
Drop-off stations /capita			6.058
			(15.87)
Intercept	0.286***	-0.0117	0.184
	(0.0279)	(0.616)	(0.555)
Additional controls	No	Yes	Yes
Observations	1,336	1,255	1,221
R-squared (within)	0.074	0.104	0.130
Number of municipalities	259	253	246

Clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Fixed effect for time (year) and entity (municipality) are included. Included control variables: population, population density, mean age, mean income, share of single-family households, education level, unemployment rate, share of foreign-born outside EU/EFTA, share of Green party voters in national election, Green party represented in local government.

6.4.2 Waste sorting through two four-compartment bins

The estimated treatment effect over time when sorting waste through two four-compartment bins is presented in table 5. A graphical illustration of the result corresponding to column (3) is presented in figure 4 in Appendix B. Once more positive and significant coefficient are estimated before, during and after introduction of curbside recycling which revile problem with endogeneity in the model. Once more the coefficient if higher the year before introduction, however, in column (3) this result is not significant.

Introduction of curbside recycling through two four-compartment bins in year *t* is associated with a marginal increase in the waste sorting degree with 6.73 percent when additional control variable are included in column (3). The coefficient is significant at a 10 percent level. The marginal increase in waste sorting degree one year after introduction is 8.84 percent, the coefficient is significant at a 1 percent level. The long run effect correspond to an increase in waste sorting degree with 8.26 percent and the coefficient is significant at a 10 percent level.

Table 5: *Estimated treatment effect over time; four-compartment bins*

VARIABLES	(1)	(2)	(3)
2 years prior	-0.00701	0.0483**	0.0391*
	(0.0255)	(0.0222)	(0.0201)
1 year prior	0.0645**	0.0973**	0.109
	(0.0321)	(0.0454)	(0.0663)
Immediate effect	0.0314	0.0440	0.0673*
	(0.0275)	(0.0292)	(0.0395)
1 year after	0.0508***	0.0628***	0.0884***
	(0.0165)	(0.0187)	(0.0203)
2 years after	0.0275	0.0377	0.0726
	(0.0282)	(0.0361)	(0.0457)
3 years after	0.0356	0.0393	0.0826*
	(0.0271)	(0.0340)	(0.0440)
Weight-based coll. fee			0.0270***
			(0.0102)
Food-waste collection			0.0385**
			(0.0154)
Drop-off stations /capita			3.962
			(16.62)
Intercept	0.297***	0.0103	0.225
	(0.0196)	(0.614)	(0.551)
Additional controls	No	Yes	Yes
Observations	1,336	1,255	1,221
R-squared (within)	0.091	0.123	0.149
Number of municipalities	259	253	246

Clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Fixed effect for time (year) and entity (municipality) are included. Included control variables: population, population density, mean age, mean income, share of single-family households, education level, unemployment rate, share of foreign-born outside EU/EFTA, share of Green party voters in national election, Green party represented in local government. Moreover, waste sorting through different coloured bags and through bags and containers are included as control variables.

6.4.3 Waste sorting through different coloured bags

The estimated treatment effect over time when curbside recycling is provided with different coloured bags is presented in table 6. A graphical illustration of the result corresponding to column (3) is presented in figure 5 in Appendix B. Only two of the included municipalities provide curbside recycling with this waste sorting system. Once more positive and significant coefficient on a 1 percent level are estimated before, during and after introduction of curbside collection in column (2) and (3) which revile problem with endogeneity in the model. Furthermore, the estimated coefficient is higher one year before introduction.

The estimated coefficients are increasing over time, indicating a better waste sorting behaviour over time, as expected. Introduction of curbside recycling using different coloured bags in year *t* is associated with a marginal increase in the waste sorting degree with 11 percent, when additional control variable are included in column (3). Hence, the direct effect on waste sorting degree is higher compared to two four-compartment bins. The marginal increase in waste sorting degree one year after introduction is 31.4 percent and 37.1 percent two years after. The long run effect correspond to an increase in waste sorting degree with 39.9 percent. This corresponds to a rather large effect, bearing in mind that the average waste soring degree among the included municipalities is 35 percent on average. However, the increase can also be explained by a higher participation rate in curbside collection schemes due to slow policy implementation.

Table 6: *Estimated treatment effect over time; different coloured bags*

VARIABLES	(1)	(2)	(3)
2 years prior	-0.00651	0.0558**	0.0564***
	(0.0264)	(0.0220)	(0.0217)
1 year prior	0.0814	0.149***	0.150***
	(0.0559)	(0.0219)	(0.0218)
Immediate effect	0.104	0.107***	0.110***
	(0.0913)	(0.0173)	(0.0171)
1 year after	0.213***	0.268***	0.314***
	(0.0447)	(0.0225)	(0.0262)
2 years after	0.265***	0.323***	0.371***
	(0.0446)	(0.0239)	(0.0272)
3 years after	0.283***	0.349***	0.399***
	(0.0449)	(0.0248)	(0.0288)
Weight-based coll. fee			0.0273***
			(0.0104)
Food-waste collection			0.0399**
			(0.0162)
Drop-off stations /capita			1.240
			(17.40)
Intercept	0.307***	0.158	0.330
	(0.0170)	(0.613)	(0.558)
Additional controls	No	Yes	Yes
Observations	1,337	1,255	1,221
R-squared (within)	0.096	0.134	0.164
Number of municipalities	259	253	246

Clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Fixed effect for time (year) and entity (municipality) are included. Included control variables: population, population density, mean age, mean income, share of single-family households, education level, unemployment rate, share of foreign-born outside EU/EFTA, share of Green party voters in national election, Green party represented in local government. Moreover, waste sorting through four-compartment bins and through bags and containers are included as control variables.

6.4.4 Waste sorting through different bags and containers

The estimated effect over time when sorting waste through bags and containers is presented in table 7. A graphical illustration of the result corresponding to column (3) is presented in figure 6 in Appendix B. Once more positive and significant coefficient are estimated before, during and up to two years after introduction in column (2) and (3) which revile problem with endogeneity in the model.

Unlike previous results the estimated coefficients are decreasing over time, indicating a weaker waste sorting behaviour over time. However, all coefficients are positive. Introduction of curbside recycling through different types of bags and containers in year *t* is associated with a marginal increase in the waste sorting degree with 6.45 percent, when additional control variable are included in column (3). This results are in line with waste sorting through two four-compartment bins. The marginal increase in waste sorting degree one year after introduction is 6.2 percent and 5.09 percent two years after. Positive but not significant coefficients are estimated in the long run.

Table 7: *Estimated treatment effect over time; bags and containers*

VARIABLES	(1)	(2)	(3)
2 years prior	0.0886***	0.0737***	0.0696***
	(0.00882)	(0.0125)	(0.0128)
1 year prior	0.0933***	0.0695***	0.0679***
	(0.00703)	(0.0126)	(0.0126)
Immediate effect	0.0890***	0.0646***	0.0645***
	(0.00748)	(0.0133)	(0.0134)
1 year after	0.0888***	0.0607***	0.0620***
	(0.0119)	(0.0160)	(0.0166)
2 years after	0.0785***	0.0468**	0.0509**
	(0.0164)	(0.0209)	(0.0203)
3 years after	0.0459***	0.0185	0.0226
	(0.00977)	(0.0167)	(0.0160)
Weight-based coll. fee			0.0272**
			(0.0107)
Food-waste collection			0.0355**
			(0.0161)
Drop-off stations /capita			0.744
			(17.64)
Intercept	0.299***	0.218	0.371
	(0.0198)	(0.623)	(0.571)
Additional controls	No	Yes	Yes
Observations	1,336	1,255	1,221
R-squared (within)	0.087	0.118	0.141
Number of municipalities	259	253	246

Clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Fixed effect for time (year) and entity (municipality) are included. Included control variables: population, population density, mean age, mean income, share of single-family households, education level, unemployment rate, share of foreign-born outside EU/EFTA, share of Green party voters in national election, Green party represented in local government. Moreover, waste sorting through four-compartment bins and through different coloured bags are included as control variables.

6.5 Sensitivity analysis, discarding the year 2007 from the regression models

Since the number of observation for the sorting degree, hence, the dependent variable in this study, is only eight in 2007 a sensitivity analysis is done where 2007 is omitted from the regression models. The results are presented in table 9 and table 10 in Appendix C. The estimated coefficients are slightly smaller when observation for the year 2007 is omitted from all the regression models, but the significance level are not changed. The significant results change from 0.180 to 0.164 when a continuous treatment variable are used (corresponding to table 2). The significant results change from 0.216 to 0.179 when estimating the effect of a transition to curbside recycling using different coloured bags (corresponding to table 3). This indicates a small overestimated effect on the waste sorting degree when introducing curbside recycling for resident living in single-family houses. This means that the previous results suffer from a small upward bias.

7 Discussion

Policy instruments will change individuals behaviour in terms of relative prices, budget and time constraints (Brekke, Kverndokk & Nyborg, 2003). Curbside recycling is an incentive-based policy instrument used to increase the voluntary recycling effort among households. The purpose of this study was therefore to estimate the change in waste sorting degree in Swedish municipalities when residents living in single-family houses made a transition from drop-off recycling to curbside recycling of packaging waste and newspaper. And moreover, to estimate the effect of three different waste sorting systems used for curbside recycling. This was done by using fixed-effect regression models controlling for region-specific characteristics assumed to influence the waste sorting behaviour as well as additional waste management policies. However, the chosen approach is based on the parallel-trend assumption. When testing the secular time trends prior introduction of curbside recycling it was found that the time trends was different between municipalities that later on choose to implement curbside recycling, and municipalities choosing not to. The two groups did not have parallel trends in the outcome variable before treatment. The results must therefore be interpreted with caution.

In this thesis individuals' waste sorting behaviour expire from a rational choice framework where the choice to recycle or not depends on the behavioural cost associated with recycling. Since curbside recycling offers a lower behaviour cost in terms of time, effort and storage cost, the waste sorting degree in a municipality was expected to increase after a transition from drop-off recycling. When a binary treatment variable was used positive but not significant result was estimated, which is not in line with the results from previous studies. However, previous studies have estimated the effect on the amount of collected waste and not on the waste sorting degree (Best & Kneip, 2011; Hage & Söderholm, 2008). One can assume that the quantity of waste will increase over time due to changes in consumption patterns, which in turn will increase the amount of collected packaging waste. Hence, an increase in the total quantity of packaging waste collected over time does not necessarily indicate a better recycling behaviour. Moreover, a possible explanation to insignificant results in this study can be that there are few households participating in curbside recycling schemes relative to the total amount of residents in a municipality.

The different collection systems used for curbside recycling requires the households to separate waste in different ways. When a binary treatment variable was used to estimate these effects positive and significant results was estimated for waste sorting using different coloured bags, indicating an increase with 21.6 percent. However, only two of the included municipalities provide curbside recycling through this waste sorting system. Following Mattson, Berg and Clarkson (2003) who highlight the design and simplicity of a waste collection system, the use of different coloured bags would be the most transparent waste sorting system in terms of simplicity and design. A transparent collection system will lower the opportunity cost of recycling by facilitating waste sorting, which is assumed to increase households' voluntary waste sorting effort.

When a continuous treatment variable was used positive and significant coefficients was estimated, indicating an increase in waste sorting degree with 0.0018 percent when additional residents was offered curbside recycling. This result may not be surprising, but it shows the external conditions importance for households' waste sorting behaviour. Furthermore, when estimating the effect of different collection systems used, positive and significant coefficients was estimated when two four-compartment bins and different coloured bags was provided. Worth noting is that an increase in the participation rate when sorting waste through different coloured bags was associated with a larger increase in the waste sorting degree, indicating a better waste sorting behaviour with this curbside recycling system. Sorting waste with different types of bags and containers did not show significant estimates. However, in this study this waste sorting system was compounded of a group of similar but not identical waste sorting system. Since the design is assumed to have an effect on the waste sorting effort there is a possibility those estimates being skewed.

When estimating the treatment effect before, during and after implementation, positive pre-treatment effects were estimated. This reveals problems with endogeneity in the estimated models. The treatment estimates are therefore confounded and the effect on the sorting degree are most likely driven by factors not included in the models. Significant pre-treatments effects can according to Ek and Muiliute-Plepiene (2016) be explained by increased environmental awareness, for which only a proxy was included as the share of Green Party voters. The results must therefore be interpreted with caution. Introduction of residential curbside recycling for single-family houses lead to a direct increase in waste sorting degree with 11 percent in a municipality. The estimated direct effect on the waste sorting degree in a municipality when different coloured bags was used for waste sorting was 11 percent, which was higher than the direct effect associated with either four-compartment bins or bags and containers, which was 6 percent. The length of the program had a positive effect on the waste sorting degree, except if curbside recycling was provided with bags and containers. This result indicated a weaker waste soring behaviour over time. The length of the program was assumed to have a positive effect on the waste sorting degree, to some extent due to slow policy implementation, but first and foremost because changes in behaviour are assumed to take time.

This study is based on a rather small sample of municipalities introducing curbside collection between 2007 and 2015, which limits the internal and external validity of the study. Unbalanced panel data was used to examine the relationship between introductions of curbside recycling on the sorting degree among Swedish households. Since self-reported waste-data are used in the analysis, and the reliability in self-reported data is limited, incorrect information concerning waste collection can occur which can give rise to miscalculations regarding the waste sorting degree. Furthermore, there is potential sample selection bias in the analysis since not every Swedish municipality has reported data in Avfall Web during the time period. Even if regression models with fixed-effect and control variables are used, threats to the internal validity still exist from OVB affecting the waste sorting behaviour not included in the regression models. Variables that are assumed to influence individuals' self-image as a responsible person and thereby affect the waste sorting behaviour, for example, are not included. For example; the feeling of moral obligation, the belief about other's waste sorting behaviour and perceives positive externalities arising from waste sorting, which in previous studies was found to be a determinant of waste sorting behaviour (Bruvoll, Halvorsen & Nyborg, 2002; Hage & Söderholm, 2008). Moreover, other municipal attempts to increase waste sorting effort, like campaigns for a better environmental behaviour among households was not included. One can also assume that mandatory or voluntary recycling programs will affect the waste sorting effort, which this study does not control for. Furthermore, curbside collection of packaging waste and newspaper is more widespread among resident living multi-family houses compared to single-family houses (SWMA, 2016b). This is, however, not included in this study. Taking these limitations into account, the estimated coefficients are potentially biased upwards. This means that introduction of curbside recycling have a smaller effect on the waste sorting degree than this study estimates.

Recycling activities and waste sorting behaviour can be measured in different ways. In this study the composition of the waste was not taken into account, which means that wrongly sorter materials and hazardous waste thrown in the waste bin are not captured. By using another measure on waste sorting behaviour it is possible that the effect of the three different waste sorting systems used for curbside recycling would look different. Furthermore, regarding which policy instrument to use in order to increase waste sorting effort and recycling rates in Swedish municipalities, it is a trade-off between different criteria. The benefit from a potential increase in recycling rates when curbside recycling is provided must be weighed against the economic cost of implementation and maintaining of the system. For future studies within the field of waste-management and curbside recycling it would be interesting to study cost effectiveness of the three different waste collection systems presented in this study.

8 Conclusion

The aim of this thesis has been to empirically estimate the effect of a transition from drop-off recycling to residential curbside recycling on the waste sorting degree in Swedish municipalities during the time period 2007 to 2015. This has been done by using a fixed effect regression model controlling for region-specific characteristics and additional waste management policies. Positive but not significant coefficients was estimated when a binary treatment variable was used. However, when estimating the effect of a transition from drop-off recycling to three different waste sorting systems used for curbside recycling, the results show positive and significant coefficients for waste sorting through different coloured bags, corresponding to an increase in the waste sorting degree with 21.6 percent. Moreover, when a continuous treatment variable was used, positive and significant coefficients was estimated for waste sorting through either two four-compartment bins or different coloured bags, corresponding to an increase in waste sorting degree with 0.00163 and 0.00267 percent. Furthermore, the results indicate a larger direct effect on the sorting degree when different coloured bags was used for waste sorting (11 percent compared to 6 percent) and an increase in waste sorting degree over time when either two four-compartment bins or different coloured bags was used. Waste sorting through bags and containers on the other hand, was associated with a weaker waste sorting behaviour over time. However, the results must be interpreted with caution since the parallel-trend assumption is weak. Furthermore, the estimated models do potentially suffer from endogeneity problems. This indicates that the waste sorting degree in a municipality potentially is driven by factors not included in the regression models.

To conclude, even if the result of this thesis just make a small contribution to the implementation of a better waste sorting behaviour in terms of waste sorting degree with curbside collection of recyclables. Yet, it is still important to continue to examine the relation between municipal policy instruments used to increase the waste sorting effort among households. Since the amount of waste is assumed to increase over time, it is important to implement policies that provide the desired outcome: less waste and increased material recycling.

Acknowledgment

I want to express my gratitude to my supervisor, Claes Ek for engagement, comments and remarks throughout the learning process of this master thesis. I am also thankful to my fellow students and their comments on earlier drafts of my thesis.

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Appendix A.

Table 8: *Detailed variable description and expected signs*

Variable	Definition and source	Expected sign
Participation rate	A continuous treatment variable measuring the share of single-family households participating in curbside collection schemes; Source: Ek and Muiliute-Plepiene (2016)	+
Weight-based collection fee	A binary variable equal to 1 if weight-based collection fee is used and 0 otherwise; Source: Avfall Web	+
Collection of food waste	A binary variable equal to 1 if collection of food waste is provided (not included as a waste fraction in the waste sorting system) and 0 otherwise Source: SWMA (2016a)	+
Recycling stations	Number of recycling stations per capita Source: Avfall Web	+
Green party in local government	Environmental preference in local government. A binary variable equal to 1 if the Green Party is represented in the local government and 0 otherwise; Source: SKL (2015)	+
Share of Green Party voters	Environmental preference in households, measured by the share of votes on the Green party in national elections (percent); Source: SCB (2017a)	+
Population	Number of inhabitants in municipality; Source: Kolada (2017a)	+/-
Population density	Included to capture urbanization. Total population divided by the total land area of the municipality (km2); Source: SCB (2017b)	-
Age	Average age of the population; Source: Kolada (2017b)	+
Income	Average income for inhabitants between 20 and 64 years (SEK '000); Source: SCB (2017c)	-
Education	Share of population with post-secondary education (percent); Source: Kolada (2017c)	+
Unemployment rate	Open unemployment rate for people between 18 and 64 as a share of population (percent); Source: Kolada (2017d)	+
Share of single-family households	Share of single-family households. Calculated; as number of households in single-family houses/(number of households living in single-family houses + number of households living in multi-family houses); Source: Avfall Webb	+
Foreign-born	Foreign-born outside EU/EFTA as a share of population (percent); Source: Kolada (2017e)	-

Appendix B.

A graphical illustration of the result corresponding to column (3) in table 4-7 are presented. The dashed horizontal line is at zero, which corresponds to no effect on the waste sorting degree. The vertical bars around each point estimate refer to the 95 percent confidence interval (1.96 times the standard error of estimates). The confidence intervals shows the interval that contains the true value of the population parameter.

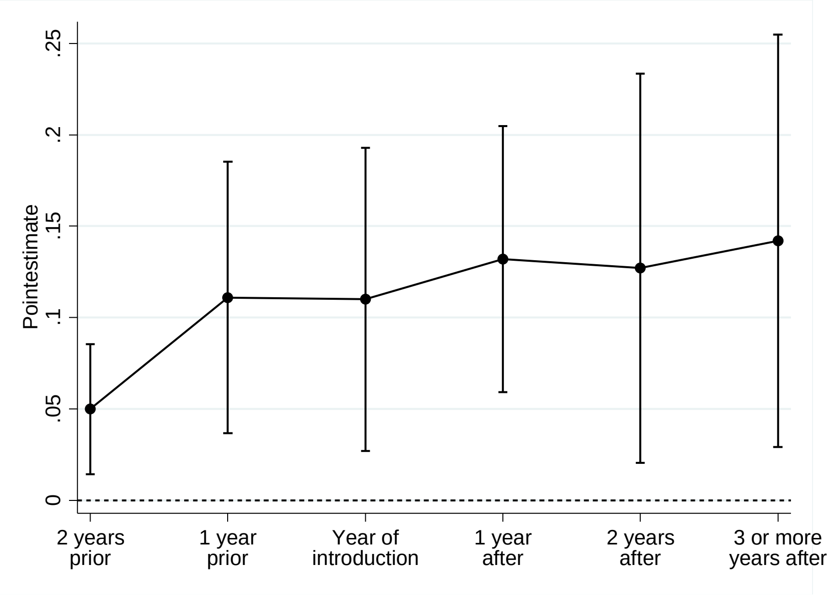

Figure 3: *Estimated treatment effect over time; curbside collection of recyclables.*

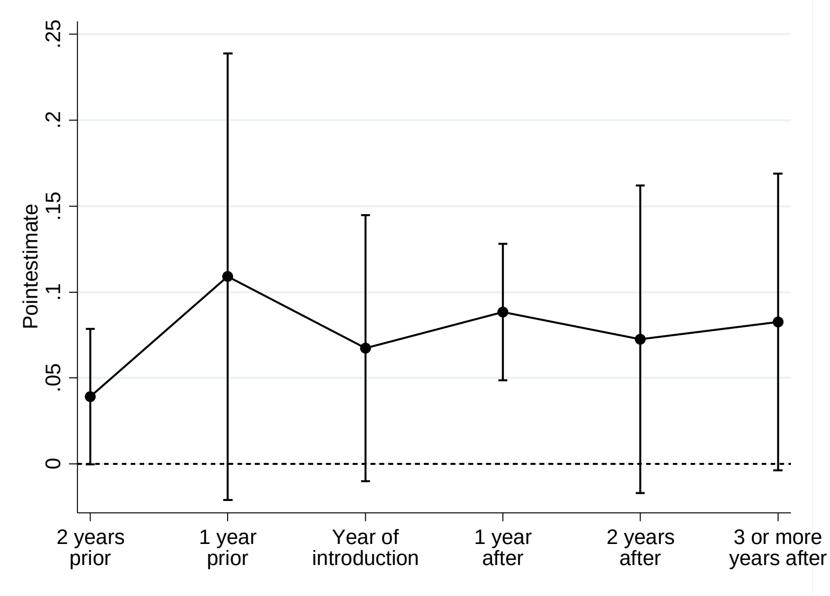

Figure 4: *Estimated treatment effect over time; four-compartment bins.*

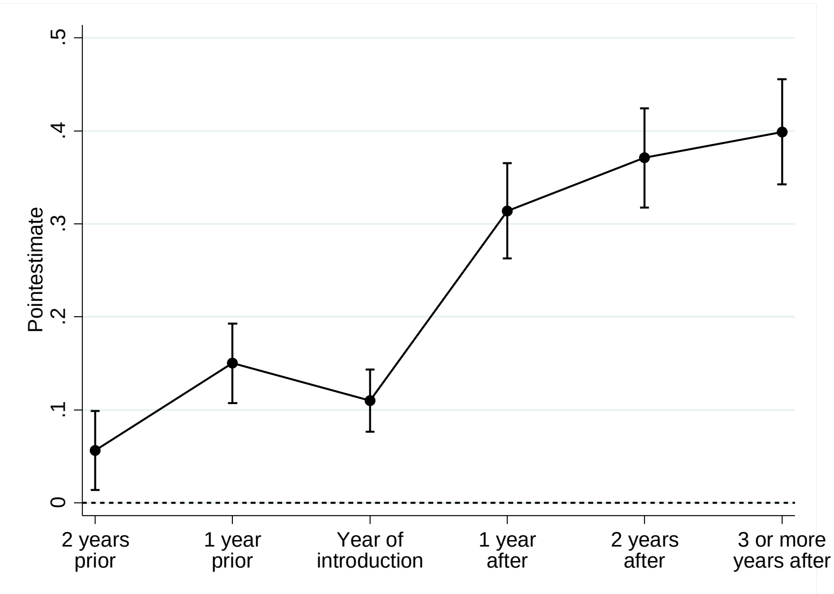

Figure 5: *Estimated treatment effect over time; different coloured bags.*

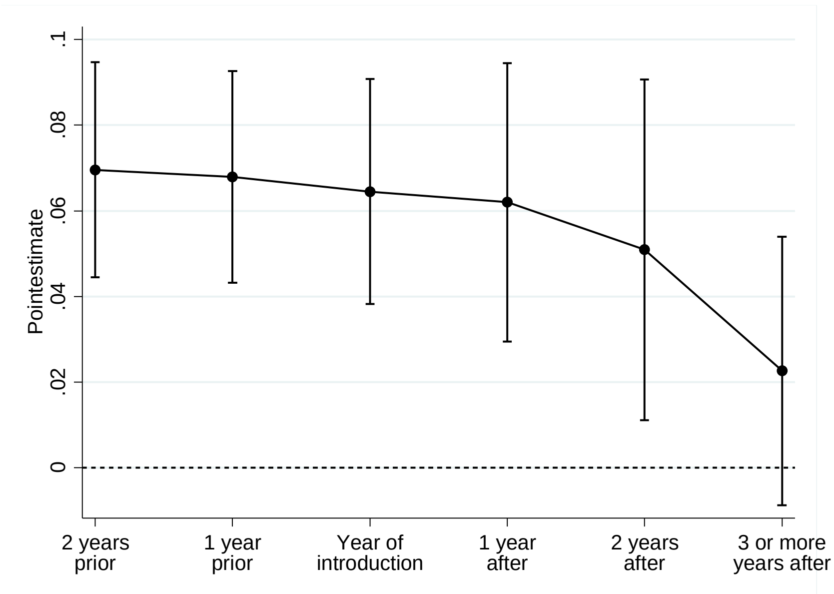

Figure 6: *Estimated treatment effect over time; bags and containers.*

Appendix C.

Table 9: Sensitivity analysis

Estimated effect of curbside collection on waste sorting degree, without the year 2007

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Curbside coll. (binary)	0.0239	0.0145	0.0359			
	(0.0218)	(0.0308)	(0.0381)			
Curbside coll. (continuous)				0.124***	0.119***	0.164***
				(0.0326)	(0.0323)	(0.0453)
Weight-based coll. fee			0.0228*			0.0233**
			(0.0120)			(0.0112)
Food waste collection			0.0344**			0.0463***
			(0.0161)			(0.0135)
Drop-off stations /capita			1.527			5.778
			(17.37)			(15.44)
Intercept	0.327***	0.238	0.400	0.325***	0.0127	0.235
	(0.0179)	(0.647)	(0.591)	(0.0158)	(0.625)	(0.548)
Additional controls	No	Yes	Yes	No	Yes	Yes
Observations	1,333	1,251	1,217	1,333	1,251	1,217
R-squared (within)	0.043	0.070	0.093	0.075	0.101	0.143
Number of municipalities	260	254	247	260	254	247

Clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Fixed effect for time (year) and entity (municipality) are included. Included control variables: population, population density, mean age, mean income, share of single-family households, education level, unemployment rate, share of foreign-born outside EU/EFTA, share of Green party voters in national election, Green party represented in local government.

Table 10: Sensitivity analysis

Estimated effect of different curbside collection systems on waste sorting degree, without the year 2007

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Four-compartment (binary)	0.00552	-0.0176	0.00933			
	(0.0202)	(0.0360)	(0.0504)			
Coloured bags (binary)	0.146*	0.150**	0.179**			
	(0.0777)	(0.0667)	(0.0808)			
Bags and containers (binary)	0.00755	-0.00259	-0.000309			
	(0.0172)	(0.0183)	(0.0179)			
Four-compartment (cont.)				0.116***	0.108***	0.163***
				(0.0243)	(0.0261)	(0.0488)
Coloured bags (cont.)				0.182***	0.182***	0.229***
				(0.0593)	(0.0498)	(0.0631)
Bags and containers (cont.)				0.00182	-0.0133	-0.0167
				(0.00494)	(0.0122)	(0.0117)
Weight-based coll. fee			0.0239**			0.0240**
			(0.0113)			(0.0111)
Food-waste collection			0.0368**			0.0485***
			(0.0161)			(0.0136)
Drop-off stations /capita			1.301			5.723
			(17.55)			(15.42)
Intercept	0.332***	0.285	0.454	0.329***	0.0172	0.241
	(0.0152)	(0.637)	(0.585)	(0.0147)	(0.626)	(0.548)
Additional controls	No	Yes	Yes	No	Yes	Yes
Observations	1,333	1,251	1,217	1,333	1,251	1,217
R-squared (within)	0.058	0.089	0.114	0.080	0.108	0.153
Number of municipalities	260	254	247	260	254	247

Clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Fixed effect for time (year) and entity (municipality) are included. Included control variables: population, population density, mean age, mean income, share of single-family households, education level, unemployment rate, share of foreign-born outside EU/EFTA, share of Green party voters in national election, Green party represented in local government.