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The weight-based tariff and recycling of cans and PET-bottles
- a study of behavioral spillovers in the context of waste sorting and recycling

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The weight-based tariff and recycling of cans and PET-bottles -a study of behavioral spillovers in the context of waste sorting and recycling

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Abstract

The aim of this paper is to investigate whether the weight-based tariff, which was introduced in nine municipalities between 2007-2017 to increase waste sorting and collection of household waste for recycling, had a behavioral spillover effect. To estimate the spillover effect, I examine whether the weight-based tariff had an effect on the recycling of cans and PET-bottles in the Swedish deposit recycling system. I exploit the staggered introduction of the weight-based tariff using a difference-in-differences approach with fixed effects. The result suggests that the weight-based tariff increased the average number of recycled cans by 3.4 cans per capita per year, implying that there is a positive spillover effect. Further analysis shows that the effect is consistent two years after the introduction of the weight-based tariff and tends to decrease after that.

Sammanfattning

EU strävar mot en cirkulär ekonomi där material och resurser bevaras inom ekonomin så länge som möjligt. För att gå mot en cirkulär ekonomi uppmanar EU-kommissionen att medlemsstaterna ska använda ekonomiska styrmedel för att förändra invånarnas konsumtionsmönster och beteenden på nationell nivå (European Commission/EU-kommissionen, 2015). Syftet med uppsatsen är att undersöka om den viktbaserade avfallstaxan som införts i ett flertal kommuner har orsakat beteendemässiga spridningseffekter. Med paneldata på kommunnivå för åren 2007-2017 undersöker jag om den viktbaserade avfallstaxan, som bland annat införts i syfte att öka källsortering och återvinning av hushållsavfall, även har en effekt på antalet burkar och PET-flaskor som pantas i Returpacks pantsystem. Metoden difference-in-differences med fixed effects används för att estimera det kausala sambandet mellan det stegvisa införandet av den viktbaserade avfallstaxan och antalet pantande burkar och PET-flaskor per capita. Tidigare studier har identifierat beteendemässiga spridningseffekter relaterat till andra reformer relaterade till miljö och avfallshantering, så som introduktionen av separata kärl för matavfall (Ek & Miliute-Plepiene, 2018). Pantsystemet har exkluderats i tidigare studier och min uppsats bidrar till förståelsen av kopplingen mellan källsortering och pantning. Resultatet visar att den viktbaserade avfallstaxan i snitt ökar antalet pantade burkar med 3,4 burkar per capita bland de kommuner som infört taxan. Den estimerade effekten på antalet pantade PET-flaskor är inte signifikanta. En mer utförlig analys av effekten över tid visar att den beteendemässiga spridningseffekten ökar upp till två år efter att den viktbaserade taxan introducerats samt antyder att effekten därefter avtar. I linje med tidigare studier av den viktbaserade avfallstaxan identifierar jag en positiv effekt på återvinningen av annat hushållsavfall så som plast, metall och papper. Uppsatsens resultat antyder att beteendemässiga spridningseffekter kan vara viktiga att ha i åtanke vid utformningen av styrmedel och reformer som riktas mot individers beteende. Insatser för att påverka hushålls avfallshantering kan därmed leda till ytterligare effekter som från början inte var förutsedda.

Table of Contents

1. INTRODUCTION **1**

2. BACKGROUND **4**

2.1 The weight-based tariff 4
2.2 The deposit recycling system 5

3. THEORETICAL FRAMEWORK **7**

4. PREVIOUS LITERATURE **10**

4.1 Weight based tariff 10
4.2 Spillover effects 11

5. DATA **14**

5.1 The dependent variables 14
5.2 The independent variable 14
5.3 Control variables 14
5.4 Limitations in the data 15

6. METHOD **16**

6.1 Difference-in-Differences 16
6.2 Fixed effects 18
6.3 Control variables 18
6.4 Sample restrictions 19

7. DESCRIPTIVE STATISTICS **20**

8. RESULT **24**

8.1 The effect of the weight-based tariff on cans and PET-bottles 24
8.2 Treatment effect over time 26
8.3 The effect on packaging waste 29

9. DISCUSSION **32**

10. CONCLUSION **36**

REFERENCES **37**

APPENDIX **40**

List of Tables

Table 1: Municipalities and introduction year of the weight-based tariff 4
Table 2: Summary of variables and the source. 15
Table 3: Summary statistics by treatment and control group 20
Table 4: The average effect on number of recycled cans 24
Table 5: The average effect on number of recycled PET-bottles per capita 25
Table 6: Treatment effect over time 27
Table 7: Packaging waste 30

List of Figures

Figure 1: Behavioral spillovers 7
Figure 2: Histograms of the yearly average number of recycled cans and PET-bottles respectively per capita. 21
Figure 3: Trend in average number of recycled cans and PET-bottles for all municipalities in the final sample. 22
Figure 4: Average number of recycled cans and PET-bottles per capita by treatment (2010) and control group. 23
Figure 5: Average number of recycled cans and PET-bottles per capita by treatment (2014) and control group. 23
Figure 6: Estimated effect of the weight-based tariff on the number of recycled cans per capita over time. 28

1. Introduction

In 2015, the European Commission (2015) adopted an EU action plan for a circular economy. A circular economy is one where materials and resources are maintained within the economy for as long as possible. The action plan states that this is essential for the EU in order to develop a sustainable, low carbon, resource efficient and competitive economy. The European Commission (2015) requires member states to use economic instruments to provide incentives and influence people's behavior on a national level. In Sweden, various policy instruments are used to target environmental behavior. For example, a flight tax was introduced to make people fly less, a subsidy for electric cars was introduced to make people buy more environmentally friendly cars, and a weight-based tariff on collection of household waste was introduced to increase waste sorting (SOU 2016:83, SFS 2017:1317, Fråne & Stare, 2014). When evaluating these policies, the costs and benefits are investigated. It is important to acknowledge that when people adopt one pro-environmental behavior, such as flying less, they might also be more inclined to adopt other pro-environmental behaviors such as using more public transport or bringing their own bag when shopping. As described by Truelove et al. (2014), if a policy targeting an initial pro-environmental behavior results in a desired subsequent behavior, the policy had a positive spillover effect. When the positive spillover effect is included in the evaluation of the policy, the benefits of the policy might be higher than expected. But there could also be a negative spillover effect which increases the cost of the policy. This happens if the initial pro-environmental behavior instead results in a reduction in people's environmental efforts in other areas. Negative spillovers can be explained by moral licensing. This implies that people performing an initial pro-environmental behavior feel justified to skip engagement in other pro-environmental behaviors because they have already done their part (Dolan & Galizzi, 2015).

The behavior of waste sorting is a pro-environmental behavior related to the recycling of cans and PET-bottles in the Swedish deposit-based recycling system. Every year over 1 billion cans and 600 million PET-bottles are sold in Sweden and about 88% are recycled in the deposit recycling system (Pantamera, 2019). According to The Bottle Bill Resource Guide founded by the Container Recycling Institute, deposit recycling systems has been implemented in countries such as Norway, Finland, Denmark, Estonia, South Korea, some parts of Canada, and some states in the US (Container Recycling Institute, 2019). The recycling rate in Finland in 2018 was 95% for cans and 90% for PET-bottles (Palpa, 2019). In Norway, the recycling rate for all cans and PET-bottles was 87% in 2019 (Infinitum, 2019). Other countries such as the UK are planning to implement a similar system to, as stated in a press release on the UK government's webpage, "increase recycling rates and slash the amount of waste polluting our land and seas" (Gov.uk, 2019). There have also been discussions about implementing a deposit recycling system on an EU level (Kommerskollegium/National Board of Trade, 2004; Motion 2016/17:589).

The deposit recycling system is separated from the waste management system of other waste and is placed in grocery stores and recycling stations all over Sweden. More than 3,000 grocery stores in Sweden provide the service of the deposit recycling system and about 97% of all recycled cans and PET-bottles are recycled in those stores (Pantamera, 2019). This suggests that most households are close to a store or recycling station where they can recycle their cans and PET-bottles, which reduces the effort and cost of recycling. If the households use the deposit recycling system instead of sorting out the PET-bottles and cans to be recycled as plastic and metal, new cans can be made without using additional material. According to Pantamera (2015), 95% energy is saved when producing a new can from recycled material. Hence, it is a pro-environmental choice to recycle cans and PET-bottles in the deposit recycling system instead of sorting it into metal and plastic waste.

In an effort to increase waste sorting and recycling of household waste, a weight-based tariff has been introduced in 32 of the 290 municipalities in Sweden (Data from Avfall Web, 2017). The weight-based tariff increases the incentive to sort out waste from the bin as each unit of waste thrown in the bin will increase the household's cost. The householders will then sort their waste and leave it at a waste station in their municipality. As they sort their waste, they could either choose to sort plastic bottles and aluminum cans into the plastic and metal waste or they could separate it from other plastic and metal waste to recycle it in the deposit recycling system. The latter choice can be viewed as a subsequent pro-environmental behavior where the first is to separate waste that can be recycled (such as plastic, metal, paper, and glass) from the waste destined for incineration. The policy designed to increase waste sorting would then have had a spillover effect where increased waste sorting resulted in an additional pro-environmental behavior, recycling of cans and PET-bottles in the recycling system.

There are several interesting aspects of this phenomenon. If a positive spillover effect would be identified it would imply that the benefits of the weight-based tariff might go beyond the calculated, making the policy more attractive. It would also indicate that the spillover effect could be extended to other related pro-environmental behaviors. A negative spillover effect, where the weight-based tariff resulted in a decrease in the recycling of cans and PET-bottles, would imply the opposite. This study will investigate the relationship between waste management and recycling in the deposit recycling system. To the best of my knowledge, there is a gap in previous research connecting the deposit recycling system to waste sorting and waste management policies. Most studies focus on effects of waste management policies on the recycling of waste sorted into plastic, metal, paper, glass, food or bulky waste where the deposit recycling system is excluded (see e.g. Andersson & Stage, 2017; Ek & Miliute-Plepiene, 2018; Hage & Söderholm, 2008). This paper also adds to the economic research on behavioral spillovers as most previous literature on the subject is in fields such as sociology and psychology. As far as I know, there is only one previous paper studying behavioral spillovers using a real-world policy and an econometric approach (Ek & Miliute-Plepiene, 2018). My paper will contribute to the research within the field by investigating the behavioral spillover effect in a previously unexplored context.

The aim of this paper is to investigate the behavioral spillover effects of the weight-based tariff in terms of the recycling of cans and PET-bottles in the Swedish deposit recycling system. This will be done by answering the research question: What is the effect of the weight-based tariff on the recycling of cans and PET-bottles?

The aim of the paper is not to evaluate whether the weight-based tariff had an effect on waste sorting and recycling of all household waste. Instead, I intend to investigate whether it resulted in an additional behavior related to waste sorting in the form of recycling of cans and PET-bottles. To answer the research question, a difference-in-differences strategy with fixed effects is used. Making use of the staggered introduction of the weight-based tariff, I measure the change in average outcomes of recycling of cans and PET-bottles between the treatment group (the municipalities that introduced the weight-based tariff) and control group (the municipalities that never introduced the weight-based tariff) before and after treatment. The results indicate a positive spillover effect showing in the recycling of cans. The recycling rate of cans increased by approximately 3.4% of the yearly population average recycling rate, which is 100 cans per capita. The estimated effect on the number of recycled PET-bottles is not significant.

The structure of the paper is as follows. The next section will provide background. Section 3 provides a theoretical framework. Section 4 contains a summary of previous literature. Section 5 contains a description of the data and the variables. Section 6 explains the method. Section 7 presents descriptive statistics. Section 8 presents the results. Section 9 contains a discussion of the results. Finally, the conclusion is presented in section 10.

2. Background

The first part of this section will provide some background information on the weight-based tariff and its implementation in Sweden. The second part will explain the deposit recycling system.

2.1 The weight-based tariff

Since 1995 a weight-based tariff has been introduced to certain municipalities in Sweden to give households incentives to reduce their household waste in bins and bags and to increase sorting of packaging- and food waste (Fråne & Stare, 2014). Fråne and Stare (2014) describe how the weight-based tariff system works in Swedish municipalities. Each municipality is responsible for its own waste management system. Most of the 290 Swedish municipalities use a volume-based tariff for household waste. In that case, households pay a fixed tariff for the volume of the bin that is collected. In 2017, 32 municipalities used the weight-based tariff (Data from Avfall web, 2017). The analysis in this paper will cover the years 2007-2017. During these years, nine municipalities introduced the weight-based tariff. The years of introduction of the weight-based tariff is presented in Table 1.

Table 1: Municipalities and introduction year of the weight-based tariff

Municipality	**Introduction of the weight-based tariff**
Bjurholm	2014
Falkenberg	2014
Gotland	2008
Göteborg	2010
Katrineholm	2010
Stockholm	2012
Vilhelmina*	2009
Vännäs	2014
Örnsköldsvik	2010

**Note*: Vilhelmina is excluded in the final sample. Only municipalities that introduced the weight-based tariff 2007-2014 are listed. Data from Avfall Web.

With the weight-based tariff, the household pays a variable tariff determined by the weight of what is actually thrown away. The intention of the weight-based tariff is to make households sort out waste such as glass, paper, metal and plastic instead of throwing all of it in the bin. The weight-based tariff is used as an economic policy instrument to increase waste sorting among those who generate waste. It can also serve as an incentive for households to reduce their waste. The design of the weight-based tariff differs between municipalities depending on what kind of households are in the program (single-family houses, multi-family houses, holiday houses, etc.), how much households pay for collection of the waste, and whether the tariff is applied to both combustible and food waste or only combustible waste.

2.2 The deposit recycling system

The deposit recycling system for aluminum cans was introduced in 1984 and ten years later PET-bottles were added to the system (Pantamera, 2019). The privately owned company Returpack AB runs the trademark Pantamera, which is in charge of the recycling system for aluminum cans and PET-bottles in Sweden. The owners of Returpack consist of representatives from companies in the trading and brewery sector (The Swedish Brewers Association, Livsmedelshandlarna, and the Swedish Food Retailers Federation). The company operates according to regulation (SFS 2005:220). The regulation states that all actors who produce ready-to-drink beverages in plastic bottles or metal cans must ensure that the bottle or can is included in an approved recycling system if the bottle or can is intended for the Swedish market. It is Returpack that is responsible for keeping the recycling system functioning. The government provides, through The Swedish Environmental Protection Agency, the corporate goal to reach a recycling rate of 90% of all cans and bottles. In 2018 the recycling rate was 85.6% for cans and 83.3% for PET-bottles. The Board of Agriculture is the supervising authority for the deposit recycling system.

All cans and PET-bottles in the recycling system have a symbol indicating that they can be recycled within the deposit system. The symbol also indicates which refund will be received when the can or bottle is recycled (1 SEK for small bottles and cans and 2 SEK for big bottles). Since the system works as a deposit system, the deposit is not included in the price of the bottles and cans when sold as beverages but is separated on the receipt as the consumer pays. When a consumer buys a ready-to-drink beverage within the recycling system, they pay a deposit separated from the price of the product. When the bottle or can is returned to the system and recycled, the same amount will be paid to the person who returned it. The deposit circulates between the producer, Returpack, the retailer and the consumer (Pantamera, 2019). When recycling within the system, consumers also have the choice to give their refund to charity instead of keeping the money for themselves. This can be an additional incentive to recycle within the system. Beyond the monetary incentives to recycle within the system, the action is also environmentally friendly (Pantamera, 2019). As the bottles and cans stay in the cycle, less energy is needed to produce new bottles and cans. A recycled can will, with no additional material added, be transformed into a new can. Compared to extracting new aluminum to produce cans, recycling demands 95% less energy. For PET-bottles, some additional material has to be added when producing the new bottle but a recycled PET-bottle is still more resource and energy efficient compared to producing a new one.

3. Theoretical framework

In this section, I will present a theoretical framework of why behavioral spillovers related to pro-environmental actions occur and how the framework can be linked to the recycling of cans and PET-bottles that is the subject of this paper.

Dolan and Galizzi (2015) review a number of studies investigating behavioral spillovers in different settings and suggest a theoretical framework that can explain the behaviors. Following their theoretical framework, behavioral spillovers can be explained by promoting, permitting or purging behavior. I applied the framework of behavioral spillovers set out by Dolan and Galizzi (2015) to the context of waste sorting and recycling. Figure 1 provides a summary of the initial and subsequent behaviors when the framework is applied to waste sorting and recycling. First, the initial behavior can be negative or positive from an environmental perspective. Second, the subsequent behavior can also be negative or positive. Most previous literature state that the

		Subsequent behavior	
		Recycle cans and PET-bottles	Dispose of cans and PET-bottles with all other waste
Initial behavior	Sort packaging waste from combustible waste	**Promoting**	**Permitting**
		Cognitive dissonance, foot-in-the-door, carry over effects of emotions, self-herding, self-signaling.	*Ego depletion, moral licensing, resting on laurels effect, single action bias.*
	Dispose of all waste as combustible waste	**Purging**	**Promoting**
		Moral cleansing, conscience accounting, moral balancing and self-concept maintenance effects.	*Self-signaling, self-inference, what-the-hell-effect.*

Figure 1: Behavioral spillovers. *Note:* The original figure can be found in Dolan and Galizzi (2015) where examples of promoting, permitting, and purging behavioral spillovers in health behavior are presented.

weight-based tariff had a positive effect on waste sorting and no study found negative effects (Andersson & Stage, 2017; Dahlén & Lagerkvist, 2010; Hage & Söderholm, 2008). Therefore, the mechanisms that explain why the subsequent behavior is positive or negative when the initial behavior is positive are what is relevant for this paper. The initial behavior investigated in this paper is the sorting of household waste. The subsequent behavior can either be to recycle cans and PET-bottles or dispose of them with other waste. The different behaviors can be explained by the mechanisms presented in Figure 1. The mechanisms behind promoting behavior suggest that increased waste sorting would result in a positive spillover effect and the permitting mechanisms suggest the opposite.

As seen at the top left of Figure 1, several mechanisms can explain promoting behavior. Explained by Dolan and Galizzi (2015), cognitive dissonance and foot-in-the-door effects are both mechanisms indicating that the preference for consistency makes people perform a subsequent pro-environmental behavior after an initial pro-environmental behavior. The essence is that people want to act in accordance with their prior actions or beliefs. Implementing the theory on the subject of this paper, it implies that the recycling of cans and PET-bottles is a pro-environmental behavior which is consistent with the behavior of sorting household waste. The carry over effects of emotions and self-herding suggest that subsequent behaviors are influenced by incidental emotions related to the initial behavior. According to these mechanisms, people would recycle cans and PET-bottles because some emotion related to the initial behavior of waste sorting makes is perceived as a deep preference for such a behavior. Finally, self-signaling explains promoting behavior as to how people signal to themselves that they are a certain type of person. Applying the mechanism to the context of this paper it would mean that people who are sorting waste signal to themselves that they are environmentally friendly. Hence, they also recycle cans and PET-bottles.

Permitting behavior, presented at the top right of Figure 1, is when the initial behavior of waste sorting is followed by disposing of cans and PET-bottles with the other household waste. The permitting behavior can be explained by a number of mechanisms (Dolan & Galizzi, 2015). Ego depletion implies that because people made a great effort in the initial behavior, they will lower their effort in the subsequent behavior. According to moral licensing, people think that if they did well with the initial behavior, they have earned to reward themselves in the subsequent behavior. Dolan & Galizzi (2015) explains moral licensing using the metaphor of a moral bank account. If people start sorting their waste due to the weight-based tariff, they will feel like they scored credits on their moral bank account. Not performing the subsequent behavior of recycling of cans and PET-bottles will result in a loss of credits. This allows people to not perform the subsequent behavior as they will have a net zero change in the credits on their moral bank account. The resting on laurels effect suggests that people can see progress, such as sorting waste, as a sub-goal and because of that not put the effort in the subsequent behavior of recycling cans and PET-bottles. Single action bias is a similar mechanism, where performing the initial behavior induces the impression that there is no need for further action.

In this paper, both positive and negative spillovers are possible and the effect will depend on what mechanism is driving the subsequent behavior of recycling cans and PET-bottles. If a decrease in the recycling of cans and PET-bottles can be found, it could be explained by the promoting spillover mechanisms. If instead an increase in the recycling of cans and PET-bottles is found, permitting spillover mechanisms could explain the result. If there would be a significant absence of any effect, it could imply that there is no connection between waste sorting and recycling of cans and PET-bottles. It would also mean that there are no behavioral spillovers connected to the recycling of cans and PET-bottles in this case.

4. Previous literature

This paper studies behavioral spillovers in the context of the implementation of the weight-based tariff. In this section, I will first provide a summary of what effects previous studies have found related to the weight-based tariff in Sweden. Second, I will review studies investigating spillover effects.

4.1 Weight based tariff

The research on the weight-based tariff is not extensive but indicates that the weight-based tariff had a positive effect on waste sorting and recycling of packaging waste. Dahlén and Lagerkvist (2010) investigated, among other things, why municipalities implement the tariff and how they perceive the results and what strengths and weaknesses could be found on the local level. With a qualitative method, the authors use descriptive data, a questionnaire, and a case study. Their main finding that could be verified was that the amount of waste in bins and bags was lower in municipalities with the weight-based tariff. However, the authors could not verify whether the lower amount of waste was due to increased waste sorting or recycling. It was confirmed that municipalities introduced the weight-based tariff with the aim to reduce waste generation and increase waste sorting and recycling and most municipalities had a positive attitude towards the tariff.

Using a quantitative approach, Andersson and Stage (2017) investigated and compared the direct and indirect effects of two policy instruments: the tariff-based system and the separate food waste collection system. The authors study how these two instruments affect the total amount of waste collected and the waste streams towards recycling, biological treatment, and incineration. Using panel data for all municipalities for the years 2007-2014, they run a fixed effects regression. The results for the weight-based tariff indicated that it reduced the amount of waste in bins and bags and increased the packaging and paper waste collected for recycling. However, as the effect on bulky waste was not significant, they concluded that the overall effect of the tariff on the total amount of waste destined for recycling was small. In part, their study investigated indirect effects, defined as the increased recycling due to the strengthened self-perception of householders as environmentally friendly and responsible. The authors mention that due to a lack of data, the study explored the effect of the tariff on how the waste was intended to be treated, not how it was actually treated.

Hage and Söderholm (2008) investigate the main determinants of collections rates of household plastic packaging waste in Swedish municipalities. Using a cross-section approach for the year 2002, they found that factors such as local policies, geographic and demographic variables, socio-economic factors, and environmental preferences can explain the collection rates in municipalities. For this paper, the most relevant finding was that municipalities using the weight-based tariff generally had higher collection rates of plastic packaging waste. The study provides evidence that the initial behavior takes place and is of importance because the subsequent behavior depends on the initial behavior.

As previous research indicates, the weight-based tariff had a positive effect on waste sorting, but the effects on recycling of different kinds of waste remain unclear. The weight-based tariff seems to increase the recycling of paper and packaging waste, especially plastic. However, the deposit recycling system has never been included in these studies. My paper will connect the previous findings related to the weight-based tariff with the spillover effects it might have had on other pro-environmental behaviors. If behavioral spillovers, positive or negative, can be found it will contribute to the understanding of the efficiency of policy instruments in waste management.

4.2 Spillover effects

Both positive and negative spillovers have been studied in different contexts. Studies have found positive relationships between a single-use carrier bag charge and other pro-environmental behaviors, fuel-efficient driving styles and intentions to reduce meat consumption, recycling and other pro-environmental behaviors such as using your own shopping bag (Thomas et al., 2016; Van der Werff et al., 2014; Berger, 1997). Negative spillovers have been found between people being environmentally friendly at home and using carbon-intensive transportation on holidays and a water conservation campaign and increased energy use (Barr et al., 2010; Tiefenbeck at al., 2013).

Although previous studies have found interesting results, not many have been using real-world policies and time series data. Neither have they investigated spillover effects in relation to different waste management policies. Ek and Miliute-Plepiene (2018) were the first to analyse behavioral spillovers using a real-world policy and robust econometric methods. To investigate behavioral spillovers in the context of waste sorting, the effect of the food waste collection system on the sorting of packaging waste was studied. They examined whether the food-only system made people sort not only more food waste but also packaging waste. Similar to my paper, they use panel data for all municipalities for the years 2006-2015 and a differences-in-differences with fixed effects approach. The results indicate that there is a positive spillover effect of about 2 kg/capita/year of packaging waste when food-only participation increased by one percentage point. The results indicate that positive spillovers can be expected in my paper as well. However, there is a difference in the policies studied, the food collection system does not produce a monetary incentive for the initial behavior, but the weight-based tariff does. Positive spillover effects in the context of waste sorting and recycling have also been found by Thøgersen (1999). The most interesting finding was that sorting household waste for recycling was correlated with making environmentally friendly choices when shopping, a result that implies that the behavior of waste sorting is linked to other pro-environmental behaviors.

Social norms could play a part in the decision to recycle cans and PET-bottles and hence be a part of the measured spillover effect. Research provides mixed results about the influence of social norms on recycling in general and the mechanisms behind it (Sharp & Thomas, 2013; Bell et al., 2011). Social norms could imply that, given a positive spillover effect, the introduction of the weight-based tariff would have a more substantial effect on recycling of cans and PET-bottles as households not directly affected by the weight-based tariff also altered their pro-environmental behavior. However, I believe that this effect would be negligible as apartment housing often is separate from single-family houses and the households not affected by the weight-based tariff would not see the waste sorting or recycling first hand and hence not be extensively exposed to the social norms.

Finally, the cost of the initial and the subsequent behavior can affect the behavioral spillovers. According to Truelove et al. (2014), negative spillovers are more likely to follow when the initial pro-environmental act was relatively easy or costless and positive spillovers are more likely when the initial act was relatively costly. Their conclusions can be applied to the context of my paper. The weight-based tariff will increase the time and effort people put in waste sorting, including sorting out cans and PET-bottles from other waste, which is a cost. However, the cost of the initial behavior of starting to sort waste can be considered to be higher than the cost of the subsequent behavior of sorting out cans and PET-bottles. Concerning the cost of recycling cans and PET-bottles in relation to waste sorting and recycling of other materials, people leave their other packaging waste at recycling stations. To recycle cans and PET-bottles, they need to go to a grocery store or a recycling station that provides the service of the deposit recycling system. It is an extra effort but the recycling of cans and PET-bottles can be made in connection to grocery shopping or recycling of other materials, so the cost in terms of both time and effort is not significant.

It is clear from previous literature that behavioral spillovers can be distinguished in different settings. Most research in the area of behavioral spillovers are from fields in sociology or psychology, and only a few use econometric analysis. This paper will hence add to the research investigating behavioral spillovers using econometric analysis. I also address the gap in knowledge about how the behavior of recycling in the deposit recycling system is related to other recycling and waste sorting behaviors.

5. Data

In the data section, I will explain the construction of the variables and the limitations of the data.

5.1 The dependent variables

The data used in this paper for the main dependent variables, the number of recycled cans and PET-bottles per resident in each municipality, was provided by Returpack. As they started to collect this type of data in 2007, no data is available for earlier years and the studied period is restricted to 2007-2017. A balanced panel is constructed with the number of cans per resident as one dependent variable and the number of PET-bottles per resident as another. Because the variables are constructed by dividing the total number of recycled cans and PET-bottles on number of residents in the municipality, the data is comparable between municipalities. I argue that a benefit with the data I use in this paper compared to the ideal case of individual-level data is that there is no unrecorded statistics in the data of recycled cans and PET-bottles.

5.2 The independent variable

I contacted the Swedish Waste Management Association (Avfall Sverige) for information about which municipalities apply the weight-based tariff and what year they introduced it. They provided the information from their database Avfall Web. Out of the 290 municipalities, 32 use the weight-based tariff, and nine of them introduced it during the period 2007-2017. A binary variable is constructed to indicate if and when the municipality introduced the weight-based tariff. The binary variable is equal to 0 if a municipality did not have the weight-based tariff in a given year and equal to 1 if a municipality had the weight-based tariff in a given year. For municipalities that never introduced the weight-based tariff, the variable will equal 0 for all observations.

5.3 Control variables

Data for control variables were provided by Statistics Sweden, Kolada, Avfall Web, HUI Research, and Ek and Miliute-Plepiene (2018). All control variables are available for the studied time period and for all municipalities, making the data set balanced. The control variables measure demographics, socioeconomic characteristics, environmental preferences, and the introduction of the food collection system.

Table 2: Summary of variables and the source.

Variable	Source of Data
Number of recycled cans per capita	Returpack
Number of recycled PET-bottles per capita	Returpack
Introduction of the weight-based tariff	Avfall Web
Population density (residents per square km)	Statistics Sweden
Share of residents with higher education	Statistics Sweden
Mean age	Kolada
Median income age group 20-64	Kolada
Unemployment age group 18-64 (%)	Kolada
Votes for green parties (%)	Kolada
Total retail revenue in million SEK	HUI Research
Food Collection system	Ek and Miliute-Plepiene (2018)

Population density is measured by the total population in the municipality divided by the square kilometer area of the municipality. Share of residents with higher education is the share of the population in the municipality with any education after upper secondary school. Percentage votes for a party with a green profile is measured as the percentage in the municipality that voted for either the Green party (MP) or the Centre party (C). A binary variable for the introduction of food-collection was constructed based on a table in online appendix A in (Ek & Miliute-Plepiene, 2018). The table provides information on what year all municipalities introduced the food-collection system.

5.4 Limitations in the data

Ideally, I would have had access to household level data on recycling and individual characteristics. Yet, there is no way to keep track of the individuals that recycle within the deposit recycling system as users never enter any personal details. The only way to get the ideal data would be to conduct a survey of a random sample of households, but then there would be a problem with households themselves estimating how much they recycle which could cause bias.

With data on the household level, it would have been possible to identify the households that are affected by the weight-based tariff and the recycling rates of those households. That would have meant more variation in the data and a higher chance of estimating a possible effect. The data used in this paper is on municipality level which means that the recycling of cans and PET-bottles performed by households not affected by the weight-based tariff, such as people living in apartments, is also included in the data. I find it reasonable to assume that the recycling of cans and PET-bottles among these households is constant over time. If that is true, the increase or decrease in the recycling of cans and PET-bottles due to the weight-based tariff should come from the households that actually are affected by the weight-based tariff.

6. Method

The paper aims to investigate the causal spillover effect from the weight-based tariff on the recycling of cans and bottles. The effect measured in this paper is driven by the households affected by the weight-based tariff. Of course, some of these households are already recycling their cans and PET-bottles and will probably continue to do so even after the weight-based tariff is introduced. The variation in the recycling of cans and PET-bottles will hence come from the households that change their behavior due to the weight-based tariff.

6.1 Difference-in-Differences

Making use of the staggered introduction of the weight-based tariff and the variation in recycling between municipalities, I use a difference-in-differences strategy with fixed effects. With the differences-in-differences strategy, the change in the recycling of cans and PET-bottles between the treatment group and the control group before and after treatment is compared. As the treatment is the introduction of the weight-based tariff, the treatment group is the municipalities that introduced the weight-based tariff and the control group is the municipalities that never introduced it. If the only difference in the change in outcome between the two groups is due to the treatment, it is possible to identify the causal effect of the introduction of the weight-based tariff on the recycling of cans and PET-bottles.

The structure of the regression will be:

$$y_{mt} = \mu_m + \lambda_t + \beta T_{mt} + \gamma \boldsymbol{X}_{mt} + \epsilon_{mt}$$

Where y_{mt} is the number of recycled cans or PET-bottles per capita in municipality *m* at year *t*. μ_m is the municipality fixed effect, and λ_t is the year fixed effect. T is the binary variable indicating treatment (=1 if the weight-based tariff was introduced in municipality *m* at year *t*, =0 if not). $\boldsymbol{X}_{mt}$ is a vector for municipality-specific controls. Finally, ϵ_{mt} is the error term. Clustered standard errors are used to correct for autocorrelation since the variables might correlate within municipalities over time.

Following Angrist and Pischke (2009), the key identifying assumption that must hold in the difference-in-differences is that the trends in the recycling of cans and PET-bottles in both treated and untreated municipalities would be the same in the absence of treatment. When this parallel trend assumption holds, the difference in the trend of the recycling of cans and PET-bottles between municipalities with and without the weight-based tariff can be measured.

Ideally, the introduction of the weight-based tariff would have been randomly assigned to municipalities. A random assignment would have implied that no municipality specific characteristics correlate with the introduction of the weight-based tariff. This is however hard to prove as reforms are not introduced completely at random, meaning that certain characteristics could influence whether a reform is introduced or not and at what time it is introduced. One argument could be that the municipalities introduced the weight-based tariff because they noticed an increase in waste sorting and recycling and hence thought it would be a good time for such a reform. I do however find that unlikely as the implementation takes time, and in their report about the weight-based tariff Fråne and Stare (2014) do not mention that as one of the reasons why municipalities introduced the weight-based tariff. In my sample, eight municipalities received treatment and it would have been ideal if the weight-based tariff had been introduced in more municipalities to get more variation and make it easier to detect a treatment effect.

Another assumption that must hold is the Stable-Unit-Treatment-Value-Assumption. The treatment status, that is whether the municipality has implemented the weight-based tariff or not, in one municipality must not affect the potential outcome in the recycling of cans and PET-bottles in another municipality. The assumption would be violated if e.g. people moved to a municipality due to recycling preferences and because that specific municipality introduced the weight-based tariff. This can unfortunately not be tested formally within the scope of this study but I find it unlikely that people base their decision to move to a specific municipality on the fact that the municipality has introduced the weight-based tariff. Another problem would occur if people go to other municipalities with a different treatment status to recycle their cans and PET-bottles. That could occur if people live close to the border to another municipality and e.g. goes for grocery shopping and recycling in the other municipality. Such behavior would result in negative bias as the increased recycling due to the weight-based tariff would not be identified in the data. Even though this might be the case for a few households, I argue that it will not affect the result significantly.

One potential problem is that the recycling rate, that is the percentage of all cans and bottles included in the deposit recycling system that is returned to the system, in Sweden is high at about 88% (Pantamera, 2019). This could mean that there is little room for more improvement, even though the target for the recycling of cans and bottles is set at 90%. However, the national recycling rate was about 79% in 2009 and there is variation in recycling between municipalities.

If a positive effect would be found, one implication would be that the effect could be even larger in countries with a lower initial recycling rate as there is more room for improvement.

6.2 Fixed effects

I include both municipality and year fixed effects. If the treated and control municipalities differ in characteristics that are constant over time, the municipality fixed effects will control for this difference. For example, if one municipality had an outstanding number of recycling stations during the whole studied time period, which could make it easier for people to recycle, the fixed effect will capture that. Hence, the trend in the recycling of cans and PET-bottles will still be parallel to other municipalities. The year fixed effect will control for all year specific factors that influenced all municipalities, such as national campaigns for recycling. I contacted Returpack (e-mail) to make sure that no recycling campaigns had been targeting municipalities at different times. If such a campaign had been introduced at the same time as the weight-based tariff, it would be hard to separate the effect from the campaign and the effect from the weight-based tariff and the result would be misleading. However, all their campaigns are on the national level, so it is not a problem. In 2016, Returpack opened the bottle deposit system for companies to voluntarily connect juice bottles, which was previously excluded. This change was national and will therefore not affect the result. Factors that influence all municipalities at the same time will have the same effect on the trends in recycling and will not be a source of bias. The SEK deposit in the recycling system is the same on a national level, and the year fixed effects will control for potential changes in the SEK deposit amount for different cans and bottles. However, to my knowledge, there have only been two adjustments during 2007-2017. First, a PET-bottle with a 4 SEK deposit was excluded from the market in 2008 due to difficulties with transportation (Blennow, 2008). Second, the deposit on cans was increased from 0.5 SEK to 1 SEK in 2010 (Sverigesradio, 2011). What remains to be controlled for is characteristics that are municipality-specific and which have changed during the studied period and might also have an effect on the recycling of cans and PET-bottles.

6.3 Control variables

The variable “population density” will control for changes in population density within a municipality. More densely populated municipalities might offer greater opportunities to recycle and it is important to keep this constant to avoid omitted variable bias. Other demographic control variables are measures of higher education, mean age, median income, and unemployment. These are included to make sure that a potential increase in the recycling of cans and PET-bottles in a municipality is not driven by a change in any of these demographic factors. I include a variable controlling for environmentally friendly preferences, measured as the percentage of votes on parties with a green profile. If there would be a shift in preferences parallel to the introduction of the weight-based tariff in a municipality, that could be what explains a higher recycling rate. A control variable for total retail revenue in each municipality is included, which capture the effect of having a larger city center or malls that could influence the availability to recycle. Finally, I control for another waste management policy, the introduction of the food waste collection system, to make sure it does not coincide with the introduction of the weight-based tariff and hence be what drives the effect.

6.4 Sample restrictions

In the original data set a few municipalities such as Strömstad and Eda had a much higher amount of recycled cans and PET-bottles than similar municipalities. This could be explained by the over border trade from Norway. Looking into this, I noticed that the municipalities on the border to Norway have a higher amount of recycled cans and PET-bottles. The trend in these municipalities cannot be assumed to be parallel to other Swedish municipalities because factors in Norway might affect the recycling in these municipalities and not in others in Sweden. To make sure that the assumption of parallel trends holds, I exclude all municipalities that are on the border to Norway in the sample. In total, 20 municipalities[1] are excluded, one of which (Vilhelmina) had introduced the weight-based tariff during 2007-2017. Further, the treatment group is restricted to the municipalities that introduced the weight-based tariff after 2007 and hence received treatment during the studied time period. The municipalities that introduced the weight-based tariff before the studied time period are excluded. This is because the difference that is to be measured is between the municipalities that never received treatment and the municipalities that received treatment during the studied time period. A list of the municipalities included in the final sample can be found in Table A1 in the Appendix.

[1]Municipalities on the border to Norway that are excluded in the sample: Arjeplog, Arvika, Berg, Dals-Ed, Eda, Gällivare, Härjedalen, Jokkmokk, Kiruna, Krokom, Sorsele, Storuman, Strömstad, Strömsund, Tanum, Torsby, Vilhelmina, Älvdalen, Åre, and Årjäng.

7. Descriptive statistics

It is of importance that the change in characteristics over time in the control group and the treatment group are not significantly different in terms of characteristics that could influence how much households recycle cans and PET-bottles. In this section, I compare the characteristics in the control group (the municipalities without the weight-based tariff) with the treatment group (the municipalities with the weight-based tariff) and present descriptive statistics. This does not say much about whether the characteristics change over time but can give an indication of whether there are any factors that could challenge the assumption of parallel trends.

Table 3 provides descriptive statistics for the control variables in the main sample by treatment and control group. The municipalities on the border to Norway are excluded. If any of the municipality specific characteristics correlate with the treatment and also correlates with the recycling of cans and PET-bottles, the parallel trends assumption might not hold. In that case, a higher or lower amount of recycling in the treatment group could be the result of a change in the characteristics that coincide with the introduction of the weight-based tariff and it would not be possible to measure the causal effect of the weight-based tariff.

Table 3: Summary statistics by treatment and control group

	Control group		*Treatment group*	
	Mean	St. dev	Mean	St. dev
Number of recycled cans per capita	100.256	28.888	104.747	15.53
Number of recycled PET-bottles per capita	56.148	14.918	54.967	11.499
Population density (residents per square km)	129.271	441.636	746.008	1545.489
Share of residents with higher education	33.216	9.651	39.078	11.766
Mean age	42.986	2.538	42.401	2.421
Median income age group 20-64 in thousands SEK	273	29.568	269	27.749
Total retail revenue in million SEK	1679.588	2589.82	14437.74	21724.85
Unemployment age group 18-64 (%)	6.423	2.462	6.622	1.853
Votes for green parties (%)	15.981	7.116	19.409	6.265
Observations	2651		88	
Municipalities	241		8	

Note: Based on the final data set where municipalities on the border to Norway and the municipalities that introduced the weight-based tariff before 2007 are excluded.

The largest differences between the control and treatment group are found in the average population density, share of residents with higher education, and total retail revenue. The differences in population density can be explained by the different sizes of the control and treatment group. There are eight municipalities in the treatment group, two of which are Stockholm and Göteborg with relatively small areas and a large population, raising the mean population density. In the control group, there are 241 municipalities. Among the ten least densely populated municipalities in the full sample, nine are in the control group which lowers the mean. This is not a problem for the study as the area is constant and I control for the change in residents per square kilometer in the regressions. What could be problematic is if the introduction of the weight-based tariff correlates with the population density. This is however unlikely because both densely populated municipalities such as Stockholm and sparsely populated municipalities such as Örnsköldsvik have introduced the weight-based tariff. The same arguments as for the difference in population density goes for the difference in total retail revenue. Finally, the difference in the share of residents with higher education between the groups is not extreme, but worth mentioning. It is important to include higher education as a control variable as it might be correlated with a pro-environmental behavior in general. It is however unlikely that the weight-based tariff is introduced because the population in the municipality has an education over average.

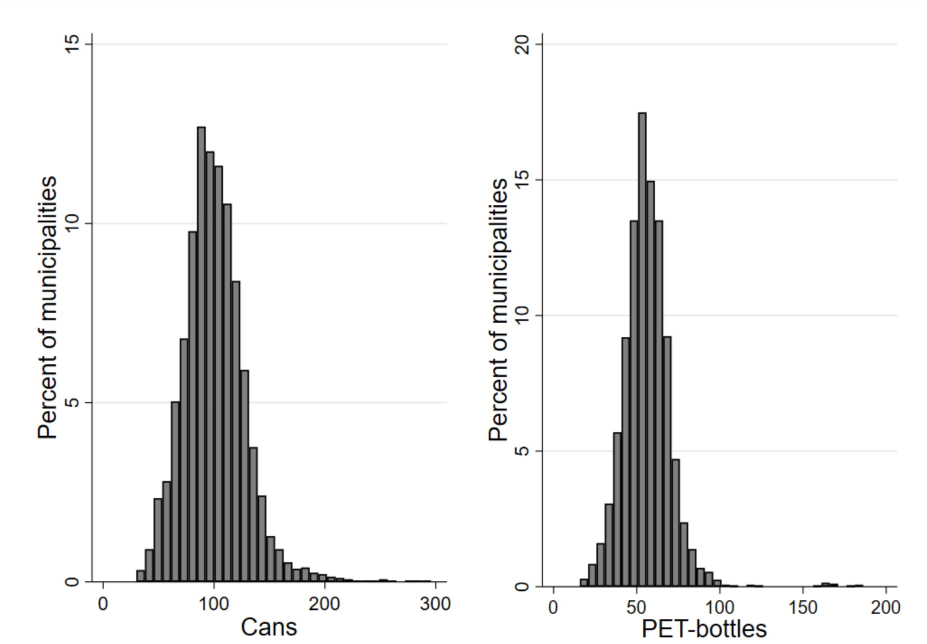

Figure 2: Histograms of the yearly average number of recycled cans and PET-bottles respectively per capita. *Note*: B Based on the final data set where municipalities on the border to Norway and the municipalities that introduced the weight-based tariff before 2007 are excluded.

Figure 2 shows that the distribution of recycled cans and PET-bottles in the full sample are right-skewed, with the mean being higher than the median. The number of recycled PET-bottles are in general about half of the number of recycled cans. On average, the number of recycled cans and PET-bottles per capita in a municipality in one year is 100 for cans and 55 for PET-bottles. The general trend in the recycling of cans and PET-bottles is displayed in Figure 3, showing a yearly increase of approximately two cans and PET-bottles per capita.

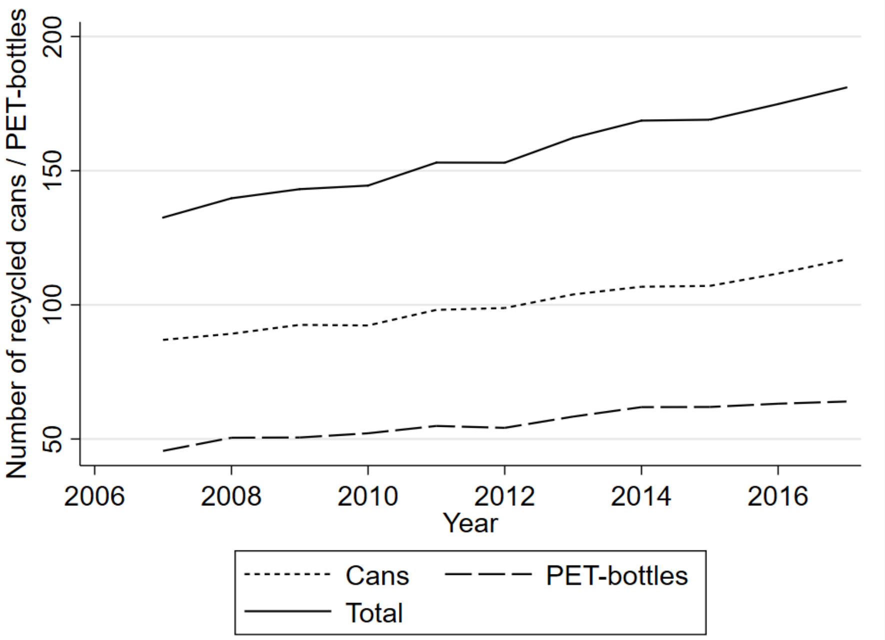

Figure 3: Trend in average number of recycled cans and PET-bottles for all municipalities in the final sample. *Note*: Based on the final data set where municipalities on the border to Norway and the municipalities that introduced the weight-based tariff before 2007 are excluded.

Figure 4 and 5 show the trends in the average number of recycled cans and PET-bottles per capita in the treatment and control groups. Figure 4 displays only the trend for the three municipalities in the treatment group that introduced the weight-based tariff in 2010 and Figure 5 shows the corresponding trend for the three municipalities that introduced the weight-based tariff in 2014. I decided to display these two sub-samples of the treatment group because of the staggered introduction of the weight-based tariff. If there would have been a clear visual effect from the weight-based tariff, it would have been hard to tell as the municipalities in the full treatment group introduced the tariff in 2008, 2010, 2012, and 2014. A corresponding graph showing the full sample can be found in the Appendix, Figure A1.

Visually, there is no sign of an effect of the weight-based tariff in the treatment group after 2010. The trend in the recycling of PET-bottles is almost identical for the treatment and control group. The average recycling of cans is slightly higher in the treatment group. Figure 5 shows that the recycling of PET-bottles in the sub-sample of the treatment group is slightly lower than in the control group.

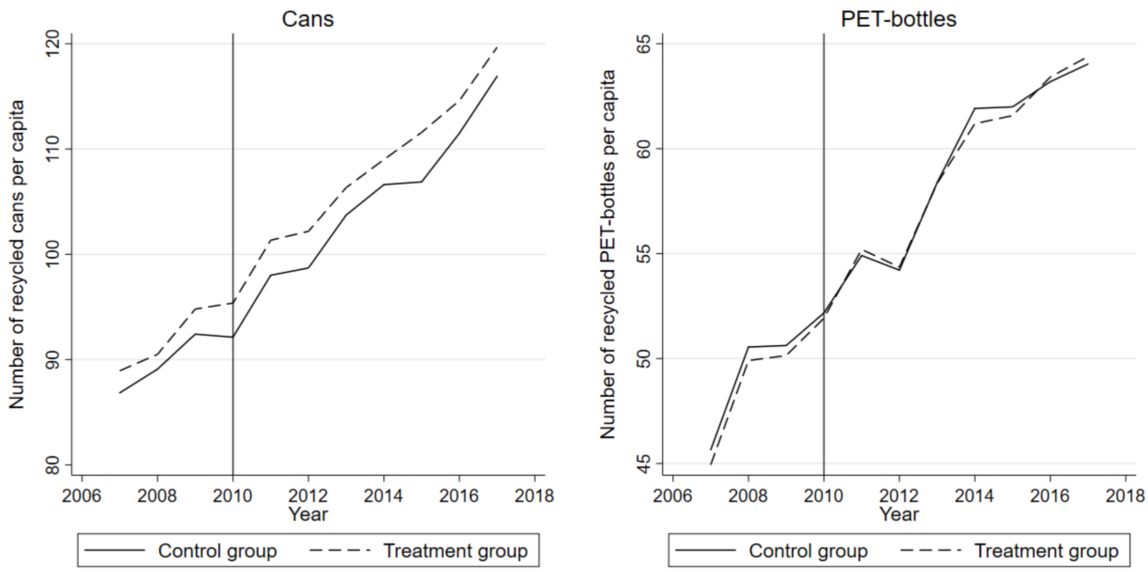

Figure 5: Average number of recycled cans and PET-bottles per capita by treatment and control group. *Note*: Only municipalities treated in 2010 are included in the treatment group in this graph. These municipalities are Göteborg, Katrineholm, and Örnsköldsvik. Based on the final data set where municipalities on the border to Norway and the municipalities that introduced the weight-based tariff before 2007 are excluded.

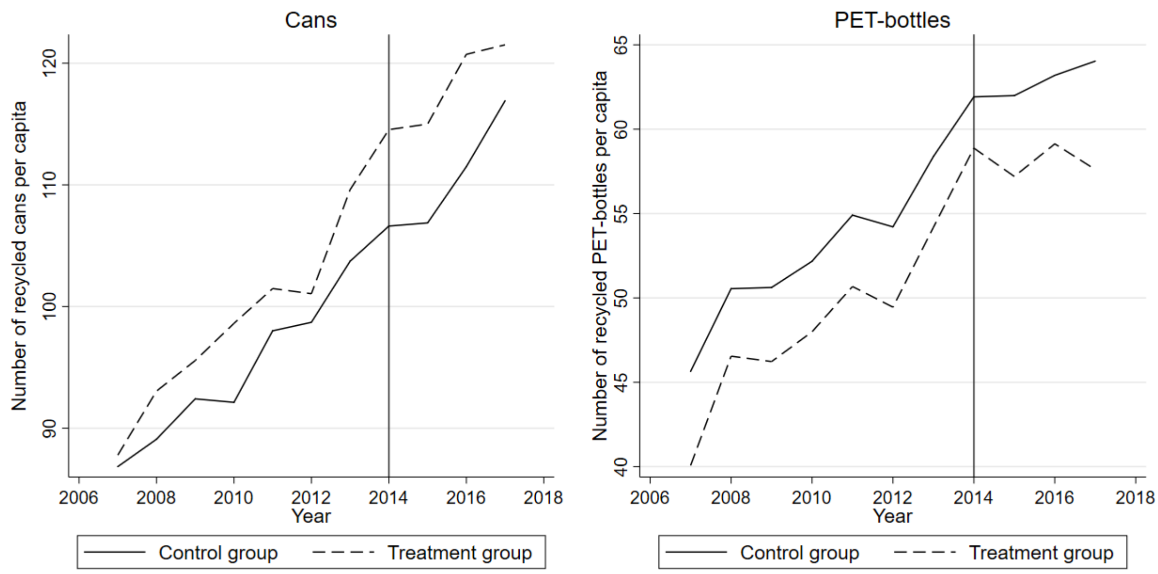

Figure 4: Average number of recycled cans and PET-bottles per capita by treatment and control group. *Note*: Only municipalities treated in 2014 are included in the treatment group in this graph. These municipalities are Bjurholm, Falkenberg, and Vännäs. Based on the final data set where municipalities on the border to Norway and the municipalities that introduced the weight-based tariff before 2007 are excluded.

These graphs indicate that the parallel trends assumption holds, as the trends in the average number of recycled cans and PET-bottles are very similar in the treatment and control group. A clear difference between the treatment and control group after the introduction of the weight-based tariff would have indicated that a causal effect of the weight-based tariff on the recycling of cans and PET-bottles could be found. However, the absence of a clear visual effect does not mean that there is no causal effect.

8. Result

The results will be presented in this section. First, I display the main result that is the effect of the weight-based tariff on cans and PET-bottles. Second, I present the estimated effect over time using leads and lags of treatment. Third, I show the effects of the weight-based tariff on collected amounts of packaging waste. The result changed considerably when certain control variables were included. This could simply imply that there is omitted variable bias when not including the controls, but it is essential that the right controls are used since the result changes depending on which ones are included. This is why I present the results including one control at a time. I reviewed the correlations between the variables to see if there was a high correlation between any of them. A correlation matrix can be found in the Appendix, Table A2. The measure of total retail revenue had a high correlation with both education and residents per square kilometer, hence I decided to remove it from all regressions.

8.1 The effect of the weight-based tariff on cans and PET-bottles

The result from the regressions with the number of recycled cans per capita as the outcome is presented in Table 4.

Table 4: The average effect on number of recycled cans

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Weight-based tariff	1.292 (2.142)	1.294 (2.128)	2.756 (1.835)	3.160* (1.833)	3.541* (1.941)	3.684** (1.813)	3.733* (2.029)	3.409** (1.721)
Food collection		0.830 (1.094)	0.885 (1.074)	0.798 (1.080)	0.927 (1.030)	1.093 (1.022)	1.055 (1.015)	1.430 (0.991)
Residents per km^2			-0.020*** (0.006)	-0.017*** (0.005)	-0.013*** (0.005)	-0.011** (0.004)	-0.010** (0.004)	-0.008** (0.004)
Mean age				1.733* (0.928)	2.690*** (0.973)	2.615*** (0.961)	2.370** (0.939)	2.007** (0.957)
Median income					-0.190*** (0.072)	-0.166** (0.071)	-0.259*** (0.079)	-0.203** (0.081)
Vote green						-0.254* (0.141)	-0.254* (0.141)	-0.266** (0.133)
Unemployment							-0.755** (0.320)	-0.698** (0.312)
Higher education								-1.016*** (0.343)
Fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Observations	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739
Municipalities included	249	249	249	249	249	249	249	249
R-squared	0.613	0.613	0.618	0.620	0.623	0.626	0.628	0.633

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Municipality and year fixed effects are included in all regressions. Median income is in thousand SEK.

One control variable at a time is included where column (1) is without control variables. Municipality and year fixed effects are included in all regressions. Although all estimates show a positive sign, the inclusion of control variables indicates that the estimates in the first columns suffer from omitted variable bias. When all control variables are included in the regression in column (8), the coefficient is significant on the 5 percent level. The estimate indicates that as the weight-based tariff is introduced the number of recycled cans per capita increases by 3.4 cans on average. As the population average of the recycling of cans is 100, the increase by 3.4 cans corresponds to a 3.4% increase of the population average.

The results for the equivalent regression with number of recycled PET-bottles per capita as the outcome are presented in Table 5.

Table 5: The average effect on number of recycled PET-bottles per capita

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Weight-based tariff	-0.125	-0.125	0.994	1.251	1.382	1.446	1.497	1.248
	(1.119)	(1.122)	(0.935)	(0.895)	(0.901)	(0.892)	(0.949)	(0.850)
Food collection		-0.113	-0.071	-0.127	-0.082	-0.008	-0.047	0.240
		(0.641)	(0.621)	(0.635)	(0.621)	(0.620)	(0.595)	(0.568)
Residents per km^2			-0.015***	-0.013***	-0.012***	-0.011***	-0.010***	-0.009***
			(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Mean age				1.104**	1.433***	1.400***	1.149**	0.870*
				(0.481)	(0.536)	(0.532)	(0.512)	(0.510)
Median income					-0.065	-0.055	-0.150***	-0.107**
					(0.048)	(0.047)	(0.045)	(0.046)
Vote green						-0.113*	-0.112*	-0.122**
						(0.066)	(0.066)	(0.060)
Unemployment							-0.772***	-0.729***
							(0.169)	(0.162)
Higher education								-0.779***
								(0.191)
Fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Observations	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739
Municipalities included	249	249	249	249	249	249	249	249
R-squared	0.732	0.732	0.741	0.743	0.744	0.746	0.752	0.761

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Municipality and year fixed effects are included in all regressions.

The results indicate a positive effect but are not significant. Here, the sign of the coefficient is negative when no controls are included and positive in column (8) with all control variables included. Since the effect of the weight-based tariff on the number of recycled cans per capita is positive and significant, it would make sense to find a similar effect on PET-bottles. The average number of recycled PET-bottles per capita per is 50, half of the average recycled number of cans. It would hence make sense if the effect on recycled PET-bottles was about half of the estimated effect on recycled cans. However, the result is not significant. One explanation could be that there is not enough variation in the recycling of PET-bottles to get a significant estimate as people recycle more cans than PET-bottles. Other possible explanations could be that people after the introduction of the weight-based tariff bought fewer PET-bottles to decrease their amount of waste or that they started to reuse the empty PET-bottles in other ways as they became more environmentally friendly.

8.2 Treatment effect over time

The assumption of parallel trends is essential in the difference-in-differences model. One way to examine whether the assumption holds is to look at the treatment effect over time, both before and after the weight-based tariff was implemented. A significant treatment effect several years before the implementation would suggest that the trends are not parallel. Column (1) to (3) in Table 6 displays the treatment effect over time on the number of recycled cans per capita and column (4) to (6) displays the equivalent effect on the number of recycled PET-bottles per capita. In the first columns, (1) and (4), no control variables are included. In column (2) and (5), I control for the introduction of the food collection system and in column (3) and (6), the full set of controls are included. The leads and lags are binary variables and equal to 1 if the year is the lead or lag year and the municipality is treated and 0 otherwise. The lead "Weight-based $\text{tariff}_{t\text{-}4\ \&\ \text{backward}}$" is equal to 1 if the year is four years prior or earlier to treatment and the municipality is treated and 0 otherwise. The lag "Weight-based $\text{tariff}_{t+4\ \&\ \text{forward}}$" is equal to 1 if the year is four years or more after treatment and the municipality is treated and 0 otherwise. For example, the binary variable "Weight-based $\text{tariff}_{t\text{-}3}$" is equal to 1 for observations where the municipality is in the treatment group and the year is three years prior to treatment and 0 otherwise. As the introduction of the weight-based tariff is staggered, this means that the lead and lag variables measure the distance to treatment effect. The "Weight-based $\text{tariff}_{t\text{-}4}$" indicates the effect four years or more prior to treatment, "Weight-based $\text{tariff}_{t\text{-}3}$" is three years prior to treatment and so on and "Weight-based tariff_{t0}" is the treatment year.

Table 6: Treatment effect over time

	Cans			*PET-bottles*		
	(1)	(2)	(3)	(4)	(5)	(6)
Weight-based tariff$_{t-4\ \&\ backward}$	1.214	1.208	0.607	0.275	0.276	-0.135
	(3.272)	(3.279)	(2.933)	(0.694)	(0.697)	(0.804)
Weight-based tariff$_{t-3}$	0.753	0.737	0.264	0.111	0.113	-0.193
	(0.505)	(0.508)	(0.785)	(0.545)	(0.546)	(0.632)
Weight-based tariff$_{t-1}$	1.578	1.591	2.867**	-0.678	-0.679	0.157
	(1.248)	(1.249)	(1.251)	(0.811)	(0.810)	(0.612)
Weight-based tariff$_{t0}$	2.748	2.690	4.269**	-0.045	-0.038	1.004
	(1.678)	(1.678)	(1.676)	(1.006)	(1.007)	(0.964)
Weight-based tariff$_{t+1}$	3.104*	3.065*	4.964***	-0.491	-0.486	0.766
	(1.707)	(1.682)	(1.520)	(0.935)	(0.934)	(0.866)
Weight-based tariff$_{t+2}$	3.811*	3.786*	5.917***	-0.130	-0.127	1.203**
	(2.073)	(2.036)	(1.674)	(0.948)	(0.953)	(0.491)
Weight-based tariff$_{t+3}$	1.441	1.437	3.736**	-1.185	-1.184	0.355
	(1.900)	(1.884)	(1.702)	(1.126)	(1.127)	(0.875)
Weight-based tariff$_{t+4\ \&\ forward}$	0.697	0.791	3.574*	0.559	0.547	2.335
	(2.793)	(2.797)	(1.898)	(2.278)	(2.280)	(1.713)
Food collection		0.799	1.411		-0.101	0.263
		(1.099)	(0.997)		(0.642)	(0.570)
Residents per km^2			-0.008**			-0.009***
			(0.004)			(0.003)
Mean age			2.037**			0.869*
			(0.960)			(0.511)
Median income			-0.205**			-0.107**
			(0.081)			(0.046)
Vote green			-0.266**			-0.122**
			(0.134)			(0.060)
Unemployment			-0.704**			-0.724***
			(0.311)			(0.163)
Higher education			-1.013***			-0.779***
			(0.344)			(0.191)
Fixed effects	YES	YES	YES	YES	YES	YES
Observations	2,739	2,739	2,739	2,739	2,739	2,739
Municipalities included	249	249	249	249	249	249
R-squared	0.613	0.614	0.633	0.732	0.733	0.761

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Municipality and year fixed effects are included in all regressions.

It is important to note that the binary variable for the lead four years prior to treatment for the municipalities that introduced the weight-based tariff in 2010 will take the value 0 as I only have data from 2007. The municipality Gotland introduced the weight-based tariff in 2008 and the lead treatment variables will hence be 0 for all years but one year prior to treatment. By the same logic, the variable "Weight-based tariff$_{t+4\ \&\ forward}$" will be equal to 0 for the municipalities that introduced the tariff in 2014. This means that the estimates of the leads and lags are not based on the exact same municipalities four years prior and four years after treatment and some of the variation will not be accounted for. This could imply that some of the estimates would be significant if I had data on an extended time period, but I argue that this is unlikely.

The reference year is two years prior to treatment and is left out of the regression. The estimates therefore show the effect in relation to the effect two years prior to treatment. I choose to not use the year prior to the treatment as the baseline year because, as shown in column (3), there is a treatment effect one year before the implementation of the weight-based tariff. In a regular difference-in-differences analysis, a significant effect the year before the treatment is introduced would indicate that the parallel trend assumption does not hold. However, in the context of this paper it makes sense. Before municipalities introduce the weight-based tariff, they are strongly recommended to send out information about the tariff to the concerned households (Fråne & Stare, 2014). As households are provided with information before the weight-based tariff is actually implemented, it is possible that they change their recycling behavior even before the weight-based tariff is officially introduced. The result in Table 6 indicates that this is the case. It is important to point out that the effect before the treatment will result in negative bias in the main result as the increase in recycling the period before the treatment is included in the control group. That negative bias indicates that the main estimates presented in Section 8.1 might be larger than estimated. There is no significant effect three years prior to treatment or earlier. The effect on the number of recycled cans per capita is significant several years after treatment with a peak two years after treatment. For the number of recycled PET-bottles, there seem to be a significant effect two years after treatment but as

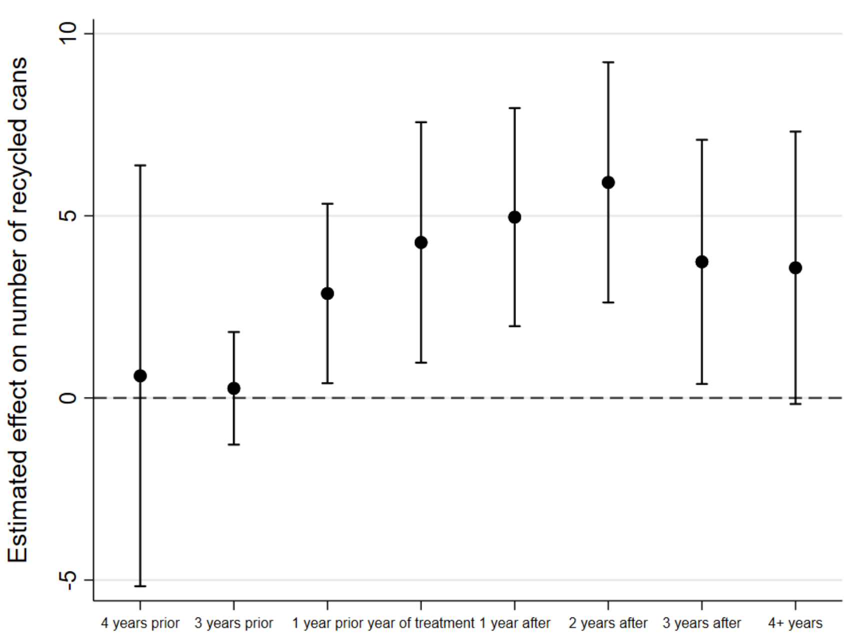

Figure 6: Estimated effect of the weight-based tariff on the number of recycled cans per capita over time. The year two years prior to treatment is the baseline year and is left out. The full set of control variables are included.

neither the main results nor any of the other estimates are significant I will not draw any conclusions based on it.

Figure 6 shows the estimated treatment effect on the number of recycled cans per capita over time, corresponding to column (3) in Table 6. An effect can be seen one year prior to treatment and consists up to four years after treatment with a peak two years after treatment. An equivalent figure for PET-bottles can be found in the Appendix, Figure A2.

8.3 The effect on packaging waste

The theory of behavioral spillovers implies that an initial pro-environmental can result in a subsequent pro-environmental behavior. In this paper, the hypothesis is that the weight-based tariff that was introduced to increase waste sorting of packaging waste (among other things). Previous studies have found that waste sorting indeed increased, even though the size of the effect is not confirmed. I accessed data on collected packaging waste from FTI (Förpacknings- & Tidningsinsamlingen), a recycling system for packaging waste and newspapers. The data is on kilograms of collected packaging waste at FTI's recycling stations per capita in each municipality for the time period 2007-2017. With this data, I change the outcome variable in my main regression from cans and PET-bottles to different types of packaging waste. I do this as a robustness check to see if I can find an effect from the weight-based tariff on packaging waste similar to what other studies have found. Ek and Miliute-Plepiene (2018) used this data to construct their outcome variables when investigating the effect of the food collection system. Andersson and Stage (2017) used similar data from another source in their analysis of the weight-based tariff but also used the FTI data as a robustness check without presenting the results. However, they state that when using the FTI data, the effect seemed to be more persistent. They use similar but not identical control variables in their regressions. If the result would imply that the weight-based tariff had an effect on packaging waste in my data as well, it would suggest that behavioral spillovers are more likely as it would confirm the initial pro-environmental behavior. Of course, previous literature has already investigated this and suggested that there is an effect. I argue that it still is relevant in this paper because if there would be no sign of an effect of the weight-based tariff on packaging waste in my data, the results for cans and PET-bottles are not very robust. Intuitively, it would be unexpected if the weight-based tariff has an effect only on cans and PET-bottles and not on packaging waste in the data I use.

Table 7 present the estimated effect from the weight-based tariff on different kinds of packaging waste. Column (6) shows the effect on the aggregated total waste. I performed all regressions in Table 7 introducing one control variable at a time. As it would take up too much space to present all the regressions, I will briefly discuss the result when including one control at a time even though I will not present the results in this paper. The effect was slightly smaller in the regressions without control variables for plastic and glass. The effect of the weight-based tariff on metal and paper waste did not change much when including controls and all regressions, with and without control variables, were significant for both metal and paper. The effect on newspaper went from negative to positive when including controls but no estimates were significant.

Table 7: Packaging waste

	Plastic	*Metal*	*Glass*	*Paper*	*Newpaper*	*Total*
	(1)	(2)	(3)	(4)	(5)	(6)
Weight-based tariff	2.002**	0.230***	1.558	3.519**	0.422	7.730**
	(0.907)	(0.074)	(1.562)	(1.446)	(2.653)	(3.483)
Food collection	0.131	0.141	1.059**	1.032**	3.805**	6.168***
	(0.295)	(0.107)	(0.467)	(0.482)	(1.637)	(1.994)
Residents per km^2	-0.002**	0.000	0.000	0.001	-0.012	-0.012
	(0.001)	(0.000)	(0.002)	(0.002)	(0.012)	(0.011)
Mean age	0.271	0.096	0.859**	0.499	0.701	2.426*
	(0.250)	(0.072)	(0.408)	(0.534)	(1.126)	(1.382)
Median income	0.023	0.014**	-0.027	0.087**	0.053	0.149
	(0.023)	(0.007)	(0.035)	(0.039)	(0.124)	(0.141)
Vote green	-0.028	0.002	-0.015	0.016	-0.420***	-0.445***
	(0.023)	(0.008)	(0.049)	(0.044)	(0.100)	(0.128)
Unemployment	0.124	0.012	-0.070	0.072	-0.660*	-0.521
	(0.080)	(0.021)	(0.138)	(0.104)	(0.377)	(0.422)
Higher education	0.054	0.046**	-0.157	0.251	-0.723**	-0.528
	(0.084)	(0.022)	(0.154)	(0.154)	(0.358)	(0.435)
Fixed effects	YES	YES	YES	YES	YES	YES
Observations	2,739	2,739	2,739	2,739	2,739	2,739
Municipalities included	249	249	249	249	249	249
R-squared	0.439	0.085	0.076	0.121	0.498	0.257

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Municipality and year fixed effects are included in all regressions.

The population average of total collected packaging waste for recycling in all municipalities in the sample is 73.2 kg/capita/year. The effect of the weight-based tariff on the total amount of collected packaging waste, presented in column (6), shows an increase by 7.7 kg/capita/year. This corresponds to a 10.5% increase of the population average. The results are in line with previous studies (Andersson & Stage, 2017; Dahlén & Lagerkvist, 2010; Hage & Söderholm, 2008) and imply that the weight-based tariff had an effect on packaging waste such as plastic, metal, and paper. Fråne and Stare (2014) state that the weight-based tariff provides incentives for people to reduce their consumption of packaging waste and if that is the case it might influence the estimates.

9. Discussion

In this section, the result will be discussed and compared with the findings of previous literature and theory. The aim of this paper was to investigate whether the weight-based tariff resulted in behavioral spillovers increasing the recycling rates of cans and PET-bottles. The result indicates that the weight-based tariff had an effect on the recycling of cans, suggesting positive behavioral spillovers. The estimates for PET-bottles are positive but not significant. This could be because there is no effect to be found or because the variation in the number of recycled PET-bottles in combinations with the limitations in the data makes it difficult to measure the possible effect.

In line with Ek and Miliute-Plepiene (2018), the result indicates that the weight-based tariff had a positive behavioral spillover effect, shown by the increased number of recycled cans. Different mechanisms can explain the direction of behavioral spillovers. The positive sign of the estimates in this paper could be explained by mechanisms such as people's preference for consistency or self-signaling. Something to acknowledge is that people individually might react differently to the weight-based tariff. Some households might start to recycle cans due to their preference for consistency. That is that they sort other household waste and therefore feel obliged to perform similar behaviors in order to be consistent. Other households might act according to moral licensing and as they start sorting waste, they stop recycling cans and PET-bottles. These two mechanisms work in different directions and hence the effect estimated in this paper could be both over- or underestimated depending on which mechanism is stronger. The estimates in this paper correspond to the average effect among the treated municipalities and it is hard to draw the conclusion that there was only a positive effect as it is difficult to separate the mechanisms. The overall average estimated spillover effect on the number of recycled cans is positive, which indicates that the mechanisms behind the promoting behavior drive the effect.

The result indicates that the weight-based tariff is effective as a policy instrument if the aim is to increase waste sorting and the recycling of both household packaging waste and cans in the deposit recycling system. The size of the effect is, however, smaller than the effect found by Ek and Miliute-Plepiene (2018). Ek and Miliute-Plepiene found that the introduction of the food collection system had a positive spillover effect on 5-10% of the population average. The corresponding spillover effect I found is approximately 3-4% of the population average and the effect is limited to the recycling of cans. If the estimated effect on the recycling of PET-bottles would be significant, the spillover effect would correspond to 2-3% of the population average. The already high recycling rate, which does not leave much room for improvement, could be one explanation for why the result is insignificant as it results in less variation in the recycling of PET-bottles. The analysis of the effect over time indicates two especially interesting phenomena. First, the analysis suggests that there is an effect one year prior to treatment. That indicates that people change their behavior due to the information about the weight-based tariff before it is officially introduced. If pro-environmental information, which can be distributed at a relatively low cost, can significantly affect people's behavior, it is something policymakers could make use of to encourage people to make more environmentally friendly choices. The effect one year prior to treatment also indicates that the estimated positive spillover effect might be underestimated in this paper. This is because the positive effect one year prior to treatment is linked to the control group and hence causes negative bias. Second, the analysis of the effect over time suggests that the effect decreases the third year after the introduction of the weight-based tariff. If that is the case, it could indicate that people might go back to old habits after a while and again recycle fewer cans and PET-bottles as they get used to the weight-based tariff. However, further research with more data is needed to investigate the effect over time for an extended period.

The result confirms that the behavior of waste sorting and the recycling of other materials is connected with the recycling of cans and most likely also the recycling of PET-bottles. It is difficult to say if the weight-based tariff should be considered as a policy instrument for increasing the recycling of cans and PET-bottles. To reach the Swedish goal of a 90% recycling rate more efficient policies directly targeting the recycling of cans and PET-bottles probably exist. However, the positive spillovers found in this paper suggest that the environmental benefits of the weight-based tariff might be higher than expected. The results from the analysis of other packaging waste are in line with previous studies (Andersson & Stage, 2017; Dahlén & Lagerkvist, 2010; Hage & Söderholm, 2008) and indicate that the weight-based tariff is working as intended and increased the amount of collected packaging waste for recycling.

There are several threats to the internal validity of the estimated results in this paper. First, there is the concern of omitted variable bias. Even though I have tried to control for all factors that vary over time and between municipalities, some factors are difficult to control for. For example, factors that affect mechanisms such as self-signaling, the preference for consistency or social norms are not controlled for. If a municipality has had some local campaign about pro-environmental behavior, or implemented another reform concerning an environmental behavior that could also have a positive effect on the recycling of cans and PET-bottles, it would result in upward omitted variable bias. In that case, the relationship between the weight-based tariff and the recycling of cans and PET-bottles might not be causal. The controls “Vote green” and “Higher education” control for environmental preferences to some extent, but are not perfect for capturing local environmental preferences. Another possible threat to the internal validity is simultaneous causality. That would mean that an increase in recycled cans and PET-bottles or waste sorting is the reason why some municipalities decided to introduce the weight-based tariff. Municipalities could think that it is a good idea to introduce a waste management policy because they see a trend in increased waste sorting or the recycling of cans and PET-bottles. I do, however, find that unlikely as many municipalities state that they introduced it to increase waste sorting and no other studies have found indications of such a behavior. Also, the implementation of the weight-based tariff from idea to actual introduction to households takes time. The analysis of the effect over time supports this argument as it indicates that there was no effect two or three years prior. The recycling of cans increased the year prior to the introduction, most likely because of information to households. I argue that the results indicate a causal relationship between the weight-based tariff and increased recycling of cans. Yet, due to the limitations discussed the effect could be biased upwards. The effect on recycling of PET-bottles remains unclear.

The results found in this paper can be generalized to other settings to some extent. In combination with previous research, the results imply that waste management policies similar to the weight-based tariff or the food collection system could also have positive spillover effects. It is, however, hard to say whether populations with other characteristics or in other countries would behave in a similar way. Furthermore, the findings indicate that waste sorting is connected to recycling in the deposit recycling system. As countries such as the UK are about to introduce a deposit recycling system, these findings suggest that such a system will work well given that households already act pro-environmental by sorting and recycling packaging waste. If the preference for consistency is strong among households, they will most likely recycle cans and PET-bottles in the deposit recycling system if they are already committed to waste sorting. As for the implications for the EU goal of a circular economy, these findings provide further evidence that waste management policies or environmental policies in general can have more benefits than initially assumed. I have not investigated whether the weight-based tariff also had other spillover effects on other environmental behaviors. For example, if people start sorting more waste, they might also expand their engagement in other behaviors such as eating less meat, increase their use of public transport or reducing their energy consumption. The identification of other behavioral spillovers in the setting of waste sorting and recycling is left for further research, still the result in this paper suggest that such spillovers could exist.

10. Conclusion

The aim of this paper has been to investigate if the weight-based tariff, that has been introduced to 32 municipalities since 1995, had a behavioral spillover effect showing in the number of recycled cans and PET-bottles. Studies suggest that the weight-based tariff increased waste sorting and recycling of household waste but the recycling of cans and PET-bottles in the deposit recycling system has so far been left out of previous research. This paper connects the behavior of waste sorting with the recycling of cans and PET-bottles. To estimate the relationship between the weight-based tariff and the number of recycled cans and PET-bottles, a difference-in-differences approach with fixed effects is used. The estimates suggest that the weight-based tariff increased the number of recycled cans per capita per year by 3.4 cans, an indication of positive behavioral spillovers. The estimated effect on PET-bottles was not significant. The analysis of the effect over time implies that the parallel trends assumption holds and that the causal effect has been estimated. The analysis also indicates that the behavioral spillover effect is consistent several years after the introduction of the weight-based tariff.

One ambition with the introduction of the weight-based tariff was to increase waste sorting among households. In line with previous research, I find that the weight-based tariff resulted in an increased collection of packaging waste such as plastic, metal, and paper. The increase in total packaging waste corresponds to an increase of approximately 10.5% of the population average.

Although the results indicate that the weight-based tariff resulted in behavioral spillovers, it is beyond the scope of this paper to evaluate whether the size of the spillover effect could have a significant impact on the environment and Sweden´s carbon footprint. However, the results do suggest that policies targeting pro-environmental behaviors can have a larger effect than initially assumed, which is something for policymakers to have in mind.

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Appendix

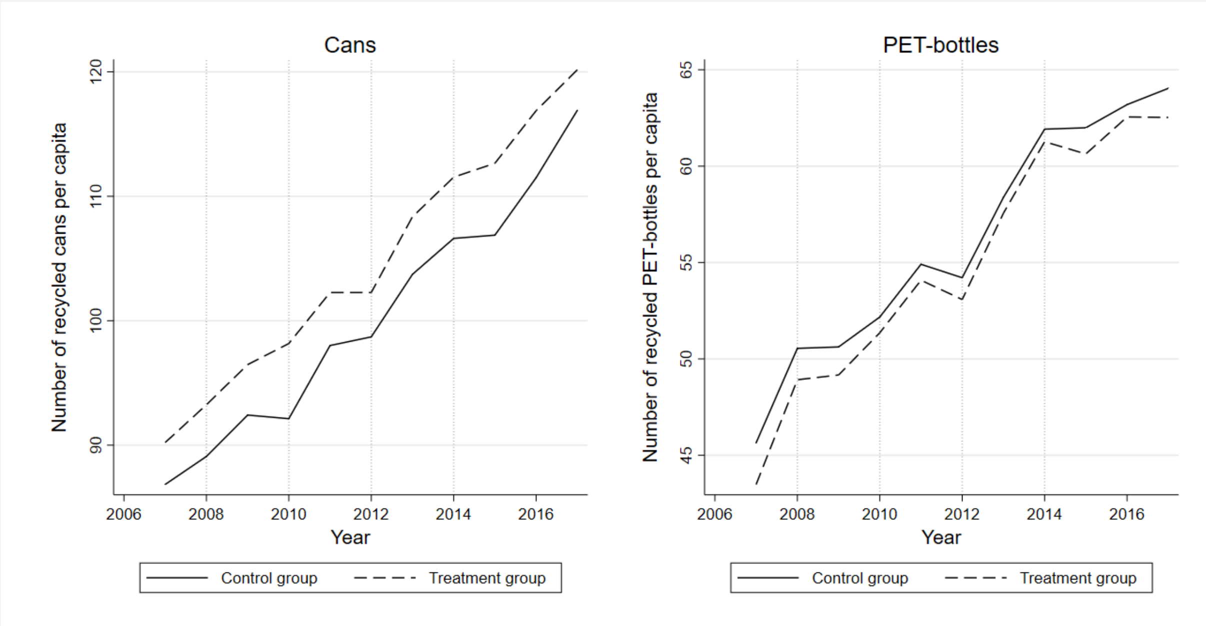

Figure A1: Average number of recycled cans and PET-bottles per capita by treatment and control group. *Note*: All municipalities treated during 2007-2014 (except Vilhelmina on the border to Norway) in are included in the treatment group in this graph. Based on the final data set where municipalities on the border to Norway and the municipalities that introduced the weight-based tariff before 2007 are excluded.

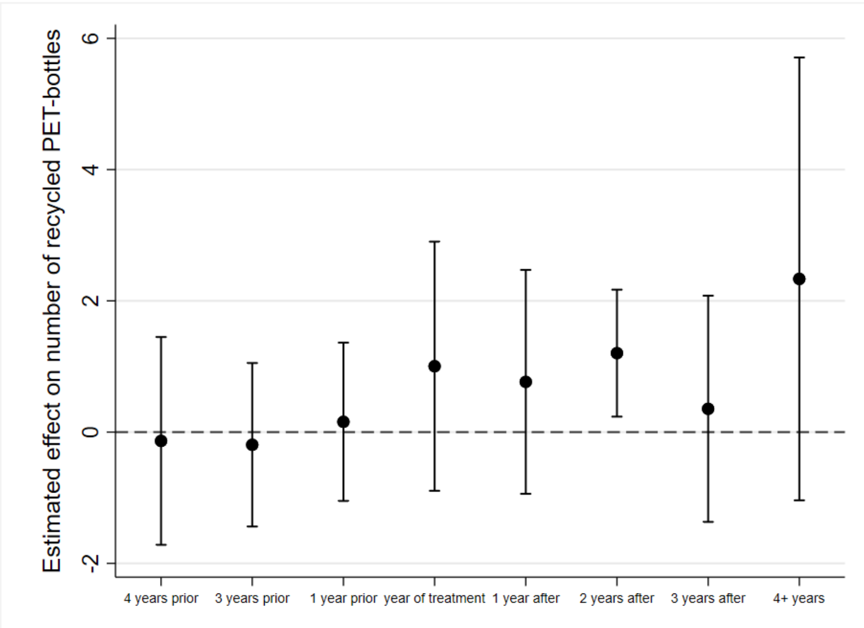

Figure A2: Estimated effect of the weight-based tariff on the number of recycled PET-bottles per capita over time. The year two years prior to treatment is the baseline year and is left out. The full set of control variables are included.

Table A1: All municipalities in the final sample by control and treatment group.

Control group				
Ale	Alingsås	Alvesta	Aneby	Arboga
Arvidsjaur	Askersund	Avesta	Bengtsfors	Bjuv
Boden	Bollebygd	Bollnäs	Borlänge	Borås
Botkyrka	Boxholm	Bromölla	Bräcke	Burlöv
Båstad	Degerfors	Dorotea	Ekerö	Eksjö
Enköping	Eskilstuna	Eslöv	Essunga	Fagersta
Falköping	Falun	Filipstad	Finspång	Flen
Forshaga	Färgelanda	Gagnef	Gislaved	Gnesta
Gnosjö	Grums	Grästorp	Gullspång	Gävle
Götene	Habo	Hagfors	Hallsberg	Hallstahammar
Halmstad	Hammarö	Haninge	Heby	Hedemora
Helsingborg	Herrljunga	Hjo	Hofors	Huddinge
Hudiksvall	Hultsfred	Hylte	Hällefors	Härnösand
Hässleholm	Håbo	Höganäs	Högsby	Hörby
Höör	Järfälla	Jönköping	Kalmar	Karlsborg
Karlshamn	Karlskoga	Karlskrona	Karlstad	Kil
Kinda	Klippan	Knivsta	Kristianstad	Kristinehamn
Kumla	Kungsbacka	Kungsör	Kungälv	Kävlinge
Köping	Laholm	Landskrona	Laxå	Lekeberg
Leksand	Lessebo	Lidingö	Lidköping	Lilla Edet
Lindesberg	Ljungby	Ljusdal	Ljusnarsberg	Lomma
Ludvika	Luleå	Lund	Lycksele	Lysekil
Malmö	Malung-Sälen	Malå	Mariestad	Mark
Markaryd	Mellerud	Mjölby	Mora	Motala
Mullsjö	Munkedal	Munkfors	Mölndal	Mörbylånga
Nacka	Nora	Norberg	Nordanstig	Norrköping
Norrtälje	Norsjö	Nybro	Nykvarn	Nyköping
Nynäshamn	Nässjö	Ockelbo	Olofström	Orsa
Orust	Osby	Oskarshamn	Ovanåker	Oxelösund
Pajala	Perstorp	Piteå	Ragunda	Ronneby
Rättvik	Sala	Salem	Sandviken	Sigtuna
Simrishamn	Sjöbo	Skara	Skellefteå	Skinnskatteberg
Skövde	Smedjebacken	Sollefteå	Solna	Sotenäs
Staffanstorp	Stenungsund	Storfors	Strängnäs	Sundbyberg
Sunne	Surahammar	Svalöv	Svedala	Svenljunga
Säffle	Säter	Sävsjö	Söderhamn	Söderköping
Södertälje	Sölvesborg	Tibro	Tidaholm	Tierp
Timrå	Tingsryd	Tjörn	Tomelilla	Torsås
Tranemo	Tranås	Trelleborg	Trollhättan	Trosa
Tyresö	Täby	Töreboda	Uddevalla	Upplands Väsby
Upplands-Bro	Uppsala	Uppvidinge	Vadstena	Valdemarsvik
Vallentuna	Vansbro	Vara	Vaxholm	Vellinge
Vetlanda	Vimmerby	Vindeln	Vingåker	Vänersborg
Värmdö	Värnamo	Västervik	Västerås	Växjö
Vårgårda	Ydre	Ystad	Älmhult	Älvkarleby
Älvsbyn	Ängelholm	Åmål	Åsele	Åstorp
Åtvidaberg	Öckerö	Ödeshög	Örebro	Örkelljunga
Östersund	Österåker	Östhammar	Östra Göinge	Överkalix
Övertorneå				

Treatment group				
Bjurholm	Falkenberg	Gotland	Göteborg	Katrineholm
Stockholm	Vännäs	Örnsköldsvik		

Table A2: Correlation matrix on control variables.

	Weight-based tariff	Food collection	Residents per km^2	Share 3+ years at university	Share with higher education	Mean age	Median income	Tot. retail revenue	Unemployment (%)	Votes for green parties (%)
Weight-based tariff	1									
Food collection	-0.014	1								
Residents per km^2	0.163*	0.059*	1							
Share with 3+ years at university	0.131*	0.190*	0.532*	1						
Share with higher education	0.110*	0.205*	0.457*	0.975*	1					
Mean age	-0.036	-0.096*	-0.341*	-0.566*	-0.617*	1				
Median income	0.047*	0.136*	0.156*	0.487*	0.495*	-0.228*	1			
Tot. retail revenue	0.370*	0.092*	0.586*	0.508*	0.466*	-0.343*	0.056*	1		
Unemployment (%)	0.047*	0.057*	-0.139*	-0.323*	-0.316*	0.382*	-0.198*	-0.037	1	
Votes for green parties (%)	0.071*	-0.117*	-0.115*	-0.160*	-0.187*	0.274*	-0.135*	-0.100*	-0.055*	1

* $p < 0.05$