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Abstract

Swedish legislation makes municipalities responsible for recycling or disposing of household waste. Municipalities therefore play an important role in achieving Sweden's increased levels of ambition in the waste management area and in achieving the goal of a more circular economy. This paper studies how two municipal policy instruments – weight-based waste tariffs and special systems for the collection of food waste – affect the collected volumes of different types of waste. We find that a system of collecting food waste separately is more effective overall than imposing weight-based waste tariffs in respect not only of reducing the amounts of waste destined for incineration, but also of increasing materials recycling and biological recovery, despite the fact that the direct incentive effects of these two systems should be similar. Separate food waste collection was associated with increased recycling not only of food waste but also of other waste. This suggests that the signalling effect of food waste collection, i.e. indirectly indicating to households that recycling is important and desirable, may be as important as direct incentive effects.

JEL classification code: Q50, Q53, Q58

Keywords: food waste collection, signalling, Sweden, waste management, waste tariffs

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Sammanfattning

EU:s avfallsdirektiv ger i fallande ordning prioritet åt förebyggande, återanvändande, materialåtervinning inklusive biologisk återvinning, energiåtervinning och bortskaffande av avfall. Den kommunala renhållningsskyldigheten innebär att kommunerna, med undantag för avfall som lyder under producentansvaret, ansvarar för att hushållens avfall återvinns eller bortskaffas. Genomslaget av den kommunala avfallspolitiken blir därmed central för att styra uppåt i avfallshierarkin. Syftet med detta avsnitt är att analysera två kommunala styrmedel; nämligen utformningen av avfallstaxan och särskilda system för insamling av matavfall. Mer specifikt studeras hur styrmedlen påverkar den totala mängden insamlat avfall liksom olika avfallsströmmar ämnade för materialåtervinning, biologisk återvinning och förbränning.

Tidigare studier från Sverige har främst studerat effekten av styrmedlen på mängden insamlad plast och blandat kärl- och säckavfall. Vi kompletterar dessa genom att analysera hur avfallstaxan och särskild insamling av matavfall påverkar andra avfallsströmmar; nämligen mängden insamlat hushållsavfall ämnat för materialåtervinning, matavfall ämnat för biologisk återvinning och kärl- och säckavfall ämnat för förbränning. Denna uppdelning gör det möjligt att öka förståelsen av hur styrmedlen påverkar olika avfallsmängder i förhållande till avfallshierarkins mål. För att förstå de underliggande mekanismerna studerar vi även hur styrmedlen påverkar insamlade avfallsmängder (kärl- och säckavfall, grovavfall, förpacknings- och tidningsavfall samt farligt avfall). Genom att studera avfallsströmmarna som sammanhållna system kan vi få en uppfattning om varifrån avfallet kommer eller tar vägen om ett styrmedel gör att en viss avfallskategori minskar eller ökar. Vidare använder vi paneldata vilket gör det möjligt att studera förändringar över tid.

Studien utgår från en teoretisk tankemodell över hur hushållen fattar sina avfallsbeslut och hur dessa beslut påverkas av styrmedlen. Baserat på teorin förväntas den viktbaserade avfallstaxan minska mängden kärl- och säckavfall ämnat för energiåtervinning, öka mängden avfall ämnat för materialåtervinning och minska totala mängden hushållavfall. Vidare förväntas särskild insamling av matavfall öka mängden avfall ämnat för biologisk behandling, minska mängden kärl- och säckavfall ämnat för energiåtervinning och öka totala mängden hushållsavfall.

Den empiriska analysen baseras på data från Avfall Sverige, Kolada och Statistiska centralbyrån (SCB). Datamaterialet sammanställts till en panel bestående av Sveriges kommuner 2007-2014 och för den ekonometriska analysen används en fixa–effekter–regressionsestimator.

Resultaten tyder på att om målet är att minska energiåtervinning och öka materialåtervinning och biologisk återvinning verkar särskild insamling av matavfall vara ett träffsäkert styrmedel. I detta avseende verkar vikttaxan inte prestera lika bra. Skillnaden i den omfördelande effekten mellan styrmedlen kan tyckas förvånande. På ett sätt kan styrmedlen ses som två sidor av samma mynt – där den viktbaserade avfallstaxan innebär en form av skatt eller sanktion på osorterat avfall, medan insamling av matavfall kan ses som en subvention för sorterat avfall. Skillnaden skulle kunna förklaras med att insamling av matavfall har ett starkare signalvärde om vad som anses vara ett miljömässigt ansvarsfullt beteende, samt att sopsortering har en självförstärkande effekt. Detta skulle kunna förklara varför insamling av matavfall påverkar mängden avfall ämnat för materialåtervinning, trots att subventionen endast berör matavfall.

1 Introduction

The purpose of this paper is to analyse two important municipal policy instruments for waste management in Sweden, namely the tariff schedule for waste management (which has been investigated in a number of previous studies) and special systems for the separate collection of food waste (which, by and large, have not). More specifically, we study how these two instruments affect the total amount of waste collected as well as how they affect the waste streams heading for recycling, biological treatment and incineration. The findings suggest that the indirect effects of waste management policies are important, possibly as important as their direct incentive effects.

Waste management is receiving increasing policy attention. This is evident in a number of new legislative proposals on waste management presented by the European Commission in 2015 and the advocacy of a "circular economy" (COM(2015) 595), among other measures. Existing European Union (EU) waste management policies prioritise, in descending order, the prevention, reuse, materials recycling (including biological recycling), energy recovery (mainly through incineration), and disposal of waste. This waste management hierarchy plays a central role in achieving a circular economy. In many EU countries, local governments are responsible for waste management, effectively making them responsible for achieving the goals of the EU's waste management policies.

In Sweden, municipalities are legally obliged to provide sanitation services at cost-recovery prices to their citizens. While dealing with certain forms of waste is the regulated responsibility of those who produce it, ensuring the recovery or disposal of household waste is chiefly the responsibility of municipalities. Thus, municipal waste policies are crucial for encouraging Swedish waste producers to move up the waste management hierarchy.

2 Waste tariffs and special systems for collection of food waste in Sweden

In terms of tariff-based waste management systems in Sweden, local municipalities have the right to charge a fee for the collection, transport, recovery and disposal of waste. This charge is not permitted to exceed the overall planning, operating and capital costs related to refuse collection (Swedish Environmental Code, Chapter 27, Section 4). Most municipalities use a volume-based tariff system, where the volume of the waste container (as well as the interval at which the waste is collected) affect the tariff that households pay (SWMA, 2015a). Some municipalities use a weight-based tariff instead, where households pay for each kilogram of waste they throw away. In 2014, 30 of the 290 municipalities in Sweden used such weight-based waste tariffs, and we compare the impact of these two tariff systems.

In respect of other systems of waste collection, e.g. special systems for food waste, Swedish municipalities vary. While some municipalities do not collect food waste separately from other forms of waste, others dictate the use of special containers or bags for food waste. The number of municipalities that collect food waste separately has increased progressively since the early 1990s: by 2014, for example, 190 of the 290

municipalities had some kind of separate collection of food waste (SWMA, 2015b). In some municipalities, there are systems for food waste collection for single-owner dwellings, apartment buildings, commercial kitchens, and restaurants. In other municipalities, there are separate food waste collection systems only for some of these market segments (SWMA, 2015a). Swedish municipalities also differ with respect to whether food waste collection is mandatory or optional, and whether or not the waste tariff differentiates between food waste and other types of waste. Moreover, there are variations in the availability of kerbside collection of packaging and in whether there are multi-compartment containers provided that make it possible to sort material by type of waste for targeted collection by the municipality.

As mentioned previously, although households are required by law to sort out certain types of waste, compliance is rarely enforced or monitored and is based largely on households' voluntary sorting (Hage et al., 2009). The waste management decisions made by households themselves will therefore determine how weight-based waste tariffs and the separate collection of food waste affect different waste streams. In the next section, we discuss how households decide how to manage their waste.

3 Waste management decisions at household level

3.1 The effects of waste management policy instruments on recycling and reduced incineration

To understand how households make their waste management decisions, consider a person who chooses between leaving some waste for recycling (including biological treatment) or throwing it all in the trash (where the waste goes to incineration, possibly for energy recovery). The benefit for the individual of leaving the waste for recycling comes partly from the ensuing improvement in environmental quality, and partly from the improved self-esteem and well-being that stem from acting not only as a morally responsible person, but also altruistically, for the good of society as a whole. However, recycling is also associated with a cost to the individual in terms of the time involved. For simplicity, assume that the benefit of throwing waste in the bin is zero, and that the cost of doing so consists of the fee that the municipality charges for collecting household waste as well as developing a bad conscience from not recycling. The individual then weighs the two options – whether or not to recycle a specific waste item – against each other and selects the one with the highest net benefit.

For an individual who lives in a municipality that levies a volume-based tariff to collect waste, s/he selects the size of bin and the collection frequency before deciding on whether or not to recycle a specific waste item. Once the disposal volume and frequency have been decided, there is no extra financial cost to the individual for throwing an additional waste item in the bin. The economic incentives for recycling in this scenario are weak, therefore.

On the other hand, if a municipality has a weight-based waste rate where the individual pays for every kilogram of waste, the net disutility of throwing an additional item of waste in the trash will be higher, and therefore it is more likely that the individual will choose to recycle and thus that materials recovery will be higher.

Similarly, biological recovery is associated with relatively high time costs when there is no separate municipal collection of food waste, because the individual household then has to engage in home composting. The introduction of a separate municipal collection system not only reduces the time cost for biological recovery for the individual, but also consequently increases the net benefits for, and the likelihood of, the individual choosing biological recovery.

Based on this conceptual model, weight-based tariffs and separate food collection appear to encourage material and biological recovery, respectively. However, the model can be extended by changing the assumptions about consumer preferences.

One such extension is that waste management policy instruments can affect the individual's self-image of being a responsible person (Nyborg, 2003; Thøgersen, 2003). On the one hand, an instrument which aims to increase recycling also, indirectly, signals that recycling is important, potentially strengthening an individual's self-perception as a responsible person when s/he recycles waste – thus increasing the likelihood of recycling. On the other hand, such an instrument may undermine the individual's internal motivation to recycle. One could argue that this internal motivation is reduced because the financial incentives provided by the instrument offer more freedom of choice: the individual may simply be willing to pay to avoid having to recycle, in which case a tariff provides the individual with the option to pay in order to circumvent developing a bad conscience (Gneezy and Rustichini, 2000).

A further extension of the model may be to take account of habit formation. Thus, households may separate their waste simply because they have always done so, rather than because they continuously weigh different options against each other and find waste separation to be the optimal behaviour. Often, however, such habitual behaviour is explained in the context of rational choice: individuals repeat a decision because doing so remains the most rational option, or because changing the behaviour in question is associated with transaction and search costs, making a change costly. It is also possible that psychological standpoints may lead to persistence in individuals' choices. For example, a person who bases his/her self-image on past actions tends to stick to a previous decision that led to those actions. Thus, although there is often persistence in choice behaviour, it is reasonable to assume (i) that there is, in the background, a decision that is based on weighing various options, and (ii) that the trade-offs between the various options can be changed if the net benefits associated with each option change sufficiently (Samuelson and Zeckhauser, 1988).

3.2 The effects of waste management policy instruments on illegal dumping and on waste generation

The conceptual model can also be extended by considering additional waste disposal options. There is a risk that the waste management decision taken by a household is not only between recycling the waste or throwing it into the garbage bin: households

can also choose to throw their waste outdoors or incinerate it themselves. Again, although both dumping and own incineration of waste is illegal, there is limited monitoring or law enforcement in this respect. Hence, the choice of one of these options is primarily likely to be prevented by a bad conscience and the individual's desire for a positive self-image. All other things being equal, however, illegal disposal should become more attractive if it is less costly than other waste disposal options. The weight-based waste tariffs thus increase the marginal incentives for illegal dumping, while separate systems for the collection of food waste are not expected to have this effect.

Furthermore, the conceptual model can be used to study how households' purchasing decisions – and, hence, their subsequent generation of waste – are affected by the two different policy instruments. A weight-based waste tariff increases the cost of producing one more kilogram of waste, which should lead consumers to buy fewer products that generate residual waste. The separate collection of food waste, however, reduces the time cost for biological recovery and should, therefore, on the margin, increase consumers' purchases of products that generate waste.

This theoretical framework indicates how incentives change qualitatively as a result of the policy instruments involved. How large these effects are, quantitatively, remains an empirical question, however.

4 Previous studies

A number of studies examine household waste behaviour and the effect of different waste management policy instruments. In the discussion below, we highlight some of the most relevant of these studies in the field.

Bruvoll et al. (2002) noted that households spend considerable time and energy on sorting waste (185 hours per tonne, on average) and, therefore, ask why households engage in waste sorting per se. Through a survey of 1,132 Norwegian households, they found that 97% engaged in waste separation because they wanted to contribute to a better environment; 73% did so because they wished to see themselves as responsible people; and 88% stated their motivation as being "I should act the way I want others to act". Nyborg (2003) interpreted the last answer to mean that households see sorting waste as being based on a moral position that conforms to what they believe is best for society.

Ålander (2013) studied the effect of weight-based waste tariffs on mixed household waste, while Hage et al. (2008) investigated, among other things, how existing tariffs affected the collection of plastic waste. Both studies used data on Swedish municipalities. For the two decades between 1992 and 2012, Ålander (2013) tracked 20 Swedish municipalities that used weight-based waste tariffs and 20 that used volume-based tariffs. Hage et al. (2008) used cross-sectional data from 282 Swedish municipalities. The results of these two studies indicated that weight-based waste tariffs led to less mixed waste and an increased amount of collected plastics. Furthermore, Ålander (2013) found that collecting food waste separately seemed to lead to less mixed household waste. Hage et al. (2008) also found that the amount of plastics collected in one municipality correlated positively with the amount collected in a neighbouring

municipality, and that kerbside collection and an increased number of recycling stations per square kilometre increase the recycling rate.

A study that takes a holistic approach to the impact of the waste management tariff is that by Dijkgraaf and Gradus (2004), who investigated how different pricing systems affected the total amount of unsorted, compostable and recyclable waste collected by Dutch municipalities. The pricing systems examined were flat rates, on the one hand, and unit-based systems, on the other, where the tariffs were calculated according to waste volume, collection frequency, the number of garbage bags, or the weight of waste collected. As in Hage et al. (2008) and Ålander (2013), the Dutch study's results indicated that a weight-based tariff system led to less total waste, with a reduction in both unsorted and compostable waste, while waste sorted out for recycling increased compared with the outcome with a flat rate.

As mentioned earlier herein, an unwanted side effect of weight-based waste tariffs is illegal disposal: households may choose the illegal options of incinerating their trash, or dumping it in impermissible locations. For obvious reasons, illegal behaviour is often difficult to measure and, therefore, rarely studied. One exception is the research conducted by Fullerton and Kinnaman (1996), who investigated how the introduction of a new waste tariff system in Charlottesville, Virginia, in the USA, affected illegal dumping there. The city switched from a system in which waste collection was funded through property taxes to a system where households paid per trash bag. To measure illegal dumping, the authors used a survey method where households could indicate if the new system had resulted in any of the following five outcomes: (i) they had attempted to reduce the amount of household waste; (ii) they had increased recycling; (iii) they had increased composting; (iv) they had begun to demand less packaging in the shops; and/or (v) they had increased the use of what the study termed "other" ways to reduce the amount of waste. Since the first four modes exhausted all legal options open to the household, the authors interpreted the fifth mode as an indicator of illegal disposal. Fullerton and Kinnaman (ibid.) also use a measure by means of which they could assume that households whose legal waste disposal had declined to zero after the new system was introduced were engaged in illegal waste disposal methods. They conclude that 28-43% of the waste reduction that arose in connection with the new system came about through an increase in the illegal disposal of waste. Although households pay per bag rather than per kilogram of waste in the above tariff-based system, this outcome nonetheless indicates some of the unwanted side effects of such systems.

As has been indicated above, waste management policy instruments may influence individuals' utility from waste recycling. This is examined by Thøgersen (2003), who asks a random sample of households about their thoughts on recycling. Households' standards are examined by allowing them to assess statements like "I think I should deliver my newspapers and magazines for recycling" and "I get a bad conscience if I do not deliver newspapers and magazines for recycling". Respondents were also asked questions such as "Do you think it is easy or difficult to deliver newspapers for recycling?" and "Do you think it is manageable or not manageable to deliver newspapers for recycling?", which all aimed at measuring their self-assessed capacity for waste management. Some of the households were based in municipalities with a weight-based waste collection tariff and some in municipalities with a flat tariff. Thøgersen (ibid.) concludes that a weight-based waste tariff did not undermine individuals' morale, but rather strengthened their perception that recycling was something in which

people should engage. Moreover, Thøgersen's study found that weight-based tariffs appeared to increase individuals' belief in their own capacity to recycle.

In order to get an overall picture, it is important not only to study policy instruments' effects on different types of waste collection and treatment, but also to know how such instruments affect municipal waste management costs. Dijkgraaf and Gradus (2015) studied how Dutch municipalities' total disposal costs, and their cost per kilogram of waste, were influenced by different pricing systems. They (ibid.) found that a fee based on weight (compared with a flat rate) reduced the total municipal costs. This cost reduction seemed to be due mainly to the reduced overall amount of waste, as the municipal cost per kilogram of waste was higher in municipalities with weight-based waste tariffs.

In a study conducted by the Swedish Waste Management Association in 2009, it was found that the additional cost of the equipment required to implement weight-based waste tariffs amounted to some 60–70 SEK (approx. 6–7 Euros) for each subscriber each year (SWMA, 2009). This can be compared with the average tariff of 2,049 SEK (approximately 200 Euros) a year for households in single-household dwellings and 1,309 SEK (approximately 130 Euros) a year for households living in apartments (SWMA, 2015a). However, as the 2009 study emphasised, the difference in the municipalities' waste management costs before and after the introduction of weight-based tariffs was partly due to the tariffs' incentive effects on household waste-sorting behaviour.

Although food waste has received a fair amount of political attention, studying the impact of separate food waste collection on waste production has received far less attention. Previous studies have determined that household food waste accounts for sizeable shares of the overall amounts of food being wasted: Gustavsson et al. (2011) estimate that households account for well over half of overall food waste in Europe – a result which is supported by other studies – and that this household waste corresponds to over a fifth of the total quantity of food available in Europe. However, research on determinants of household food waste have focused on attitudinal variables (see e.g. Cecere et al. 2014; Graham-Rowe et al. 2014) rather than on local waste management policies. Indeed, Garrone et al. (2014), modelling policies aimed at reducing overall food waste, focus on other parts of the food supply chain and merely note that waste disposal is the key policy for managing household food waste, without exploring the topic further. Thus, the effect of management policies for food waste on household behaviour is an under-investigated topic.

Moreover, previous studies of tariff instruments that have gone into detail about the type of waste collected have primarily investigated the effect of the instruments on the amount of collected plastic and mixed waste. We complement these studies by looking at how the imposition of waste tariffs and separate collection systems for food waste affect other waste streams, namely the amounts of collected waste intended for recycling, food waste intended for biological recycling, and mixed waste intended for incineration. This breakdown of the quantities of waste offers insight into how municipal policy instruments affect different types of waste in relation to the national policy targets for waste. For an enhanced understanding of the underlying mechanisms, we also study how policy instruments affect the collected quantities of several different types of waste (waste collected in bins and bags, bulky waste, paper and packaging waste, and hazardous waste). By studying the different waste streams as a cohesive

system, we can get an idea of where the waste will come from, or end up, if a policy instrument causes a certain category of waste to decrease or increase. Furthermore, in order to study changes over time, we used panel data.

5 Data

We use data from the Swedish Waste Management Association, Kolada, and Statistics Sweden (SCB). The Swedish Waste Management Association is an industry body for waste management. The organisation compiles waste-related data reported by municipalities, municipal companies and disposal facilities through its web platform, Waste Web. Kolada is a database that contains key figures on municipalities' and counties' activities, mainly based on figures from Statistics Sweden. The data were compiled into a panel of Swedish municipalities across a date range of 2007–2014. A total of 27 municipalities that conduct waste operations jointly – and, therefore, also report jointly – were deleted from the panel because the main policy variables varied among the cooperating municipalities, and because the municipalities included in the various collaborations varied across the time period in question.

There are at least two ways to categorise household waste: the type of waste collected, and its intended treatment. Thus, the waste collected can be subdivided by type into the following categories: waste collected in bins and bags, bulky waste, paper and packaging waste, and hazardous waste. The waste collected can be sorted by intended treatment into biological treatment, recycling, incineration, or other treatment such as disposal. Our data set includes all the categories of collected waste as well as certain treatment categories, namely food waste destined for biological treatment, waste destined for recycling, bins and bags of waste destined for incineration, or waste destined for other treatment. However, it needs to be borne in mind that the data describe how the waste was destined to be treated, not how it was actually treated. Thus, for example, it is possible that some food waste is destined for biological treatment, but because other waste has incorrectly been mixed into it, the food waste has to be incinerated.

The descriptive statistics of the variables used in the data analysis are presented in tabel 1below, while facts 1 provides details on the classifications used, including how the various categories of waste are related, and how they fit into the European Union's waste management hierarchy.

Weight-based waste tariffs were used in about 10% of the cases, while the separate collection of food waste occurred in about half of the cases. The background variables used in the analysis are the number of inhabitants in the municipality; number of households in one- or two-household dwellings; the number of vacation dwellings; average income in SEK '000; the percentage of unemployment; average age; percentage of inhabitants with tertiary education; and percentage of voters who voted for the Green Party in the last municipal election. The last-mentioned variable is used as a proxy for especially strong environmental preferences; this variable has also been included in previous studies (see e.g. Hage and Söderholm 2008).

Tabel 1 Descriptive statistics

Variable	N	Average	Standard deviation	Min	Max
Variables for type of household waste collected (kg / adjusted population)					
Total quantity of household waste	1,364	502.4	118.2	148.9	1016.0
Waste in bins and bags	1,638	218.6	44.3	23.0	454.0
Bulky waste	1,531	179.6	100.3	1.8	686.0
Paper and packaging waste	1,554	75.2	21.9	0.0*	201.0
Hazardous waste	1,492	25.2	8.3	0.0*	64.8
Variables for destination of household waste (kg / adjusted population)					
Food waste for biological treatment	879	32.4	28.9	0.0	121.0
Bin and bag waste for incineration	1,602	198.7	56.9	25.0	454.0
Materials for recycling	847	125.2	30.5	54.0	333.0
Other treatment	662	177.9	88.0	9.3	566.6
Policy variables					
Weight-based tariff (dummy)	2,111	0.1	0.3	0.0	1.0
System for collection of food waste (dummy)	1,887	0.5	0.5	0.0	1.0
Background variables					
Number of inhabitants in municipality	1,954	34661.1	70357.9	2421.0	911989.0
Number of households living in one- and two- household dwellings	1,515	0.6	0.2	0.0	1.0
Number of vacation dwellings	1,532	1884.2	2454.9	0.0	25407.0
Average income (SEK '000)	2,096	247.6	35.8	189.8	520.1
Unemployment (%)	2,096	6.3	2.5	1.1	17.2
Average age	2,096	43.0	2.6	36.1	49.4
Share of population with tertiary education (%)	2,096	30.6	9.7	16.4	73.9
Share of Green Party voters (%)	2,096	4.4	2.5	0.1	16.6

Note: Extreme values have been dropped using the Bacon algorithm in Stata. Adjusted population, a measure developed by the Swedish Waste Management Association, is used to adjust for people – apart from the specific municipality's own population – who contribute to that municipality's overall waste production. The measure is adjusted for the number of vacation dwellings, commuting and guest nights. Sensitivity analyses were carried out where observations with reported zero values for one or more types of waste were dropped. Figures may not sum exactly to reported totals owing, for example, to differences in the number of observations used to calculate averages for different variables.

Facts 1: Classifications used for the waste categories

Household waste by type collected

Bin and bag waste consists of household waste that can be incinerated as well as food waste.

Bulky waste consists of e.g. gardening waste, wood waste, metal waste, bulky packaging and other waste collected e.g. at municipal recycling stations or in special kerbside containers. Some of this is destined for material recycling and the rest for "other" treatment.

Paper and packaging waste consists of paper, plastic, glass and metal packaging covered by producer responsibility regulations as well as newspapers. This waste is destined for material recycling.

Hazardous waste consists of electrical and battery waste as well as those hazardous household waste that the municipality is responsible for. This waste is destined for "other" treatment.

Household waste by intended treatment

Food waste for biological treatment includes e.g. food waste treated through centrally organised anaerobic digestion, centrally organised composting, home composting, and food waste which is collected through garbage disposal units connected to central networks. This category belongs to the "Material recycling including biological recycling" part of the EU waste hierarchy.

Bin and bag waste for incineration comprises combustible waste for municipalities that have separate collection of food waste and mixed waste for those municipalities that do not. This category belongs to the "Material recycling including biological recycling" part of the EU waste hierarchy; almost all waste incineration in Sweden is linked to district heating.

Materials for recycling includes materials that are collected through producer responsibility regulations and other material collected through municipal recycling establishments, e.g. metal waste. This category obviously belongs to the "Material recycling including biological recycling" part of the EU waste hierarchy.

Other treatment is the difference between the total household waste collected and the waste types treated in some other fashion. This category includes landfill and bulky waste that is incinerated or (in rare cases) treated in some other fashion. Most of this belongs to the "Other disposal" part of the EU waste hierarchy, though some is used for energy recovery.

6 Method

In order to evaluate the impacts of the tariff schemes, we used the residents of municipalities that did not have such tariff schemes as a control group. To control for variation in the amount of waste that is due to factors other than the design of the waste tariff, we included the background characteristics presented in Table 1 in a regression analysis. Furthermore, in order to control for unobservable differences among municipalities, we used a fixed effects regression estimator. The econometric specifications used follow the structure –

$$Y_{it} = \beta S_{it} + \alpha B_{it} + c_i + d_t + \varepsilon_{it}$$

where Y is the outcome variable for municipality i during time period t, S denotes various policy instruments, B is a vector of background variables, c denotes time-invariant municipality-specific effects, d denotes time-specific effects, and ε is a normally distributed residual term.

Because there may be a delay between the point at which a new system is introduced and that at which it achieves its full effect, we also studied the effect of the introduction of policy instruments as well as the effect of such instruments being in place for one year, for two years, and for more than three years. Thus, can be written as –

$$\beta S_{it} = \beta_{11} Weightimpl_{it} + \beta_{12} Weight1yr_{it} + \beta_{13} Weight2yrs_{it} + \beta_{13} Weight3yrs_{it} + \beta_{21} Food\ impl_{it} + \beta_{22} Food1yr_{it} + \beta_{22} Food2yrs_{it} + \beta_{23} Food3yrs_{it}$$

where *Weightimpl* is a dummy which is set to 1 for the year in which the weight-based tariff was implemented, while *Weight1yr*, *Weight2yrs* and *Weight3yrs* are set equal to 1 if the weight-based tariff had been in place for one, two, and three or more years, respectively. This means, for example, that can be interpreted as the effect of having had a weight-based tariff in place for one year, compared with what would have been the case if no such tariff had been implemented. Separate food waste collection was studied in an analogous fashion.

We examined the effects of the two sets of policy instruments on the collection of waste by type as well as by intended treatment. Based on the conceptual model discussed above, we expect the weight-based waste management tariff to reduce the amount of waste collected in bins and bags – including both waste intended for incineration and food waste intended for biological treatment – and to reduce the total amount of household waste. Based on the same model, the amount of waste for materials recycling – including paper and packaging waste – might either increase or decline, depending on whether the effect on sorting or the overall reduction effect dominates. Furthermore, separate collection of food waste is expected to increase the amount of waste destined for biological treatment, in turn reducing the amount of waste collected in bins and bags and destined for incineration, and increasing the total amount of household waste, but with no a priori expectations of effects on other types of waste. It is likely that the amount of waste also varies among municipalities depending on residents' income, education, employment, age and the breakdown between the number of households in one- and two-household dwellings, apartment buildings and vacation dwellings.

7 Results

The results in table 3 indicate that the weight-based waste tariff reduces the amount of bins and bags of waste. This is in line with findings by Ålander (2013), namely that weight-based tariffs reduced the amount of mixed waste. Bins and bags of waste include waste intended for incineration and food for biological treatment.

However, if one looks at the results in table 2, only the effect on food waste destined for biological treatment is statistically significant. One explanation for this effect could be that the tariff may lead households to plan their food consumption better, resulting in less food being discarded.

Furthermore, weight-based tariffs do not have any significant effect on the amount of waste destined for recycling. Waste intended for recycling includes paper and packaging waste as well as waste collected through recycling centres and intended for recycling. Previous studies (see e.g. Hage et al. 2008) found that weight-based tariffs increased the amount of sorted plastic waste. In the current study, we found (table 3) that weight-based tariffs increased the amount of collected paper and packaging waste; however, the results showed no effect on the amount of bulky waste collected. Thus, although weight-based tariffs seem to have a positive effect on certain waste streams intended for recycling, the effect does not appear to be large enough to affect the overall amount of waste destined for recycling.

The results in table 2 indicate that having a separate system for the collection of food waste increases the amount of food waste destined for biological treatment, reduces the amount of bin and bag waste intended for incineration, and increases the amount of waste for recycling. Similarly, the results reported in table 3 indicate that separate food waste collection leads to more paper and packaging being collected separately from general bin and bag waste, as well as statistically significant effects on the collection of bulky waste and hazardous waste.

It is noteworthy that having a separate system for the collection of food waste increases the amount of waste for recycling; it would have been more logical if separate food waste collection led to waste being redistributed from bins and bags for incineration to food waste for biological treatment. One possible explanation for this unexpected result may be that, when municipalities introduce separate systems for the collection of food waste, this simultaneously signals that waste separation is desirable in general. If we assume, in line with Nyborg (2003), that households base their waste management decisions on what they consider to increase society's overall welfare, the separate collection of food waste may affect the individual's perception of what is good for society. When this occurs, it may also, indirectly, change other household waste disposal behaviour – in this case it may tend to increase waste separation. We found that the increase of waste intended for recycling appears to occur through an increase not only of the collected amounts of paper and packaging waste, but also of the collected amounts of bulky waste.

It may also be that individuals have a desire to act in accordance with their self-image, which in turn is based on their past actions. Thus, if collecting food waste strengthens the individual's perception of him- or herself as an environmentally responsible person, that individual may also wish to act in accordance with this positive image in other areas as well, e.g. by sorting other waste as well.

Another explanation could be that the system of collecting food waste separately correlates with other waste management policies for which we were unable to control. However, it should be borne in mind that the other policies for which we could control appear to have had little impact.

Alternative model specifications were estimated for each of the models reported in table 2 and 3 in order to reduce the risk that minor choices in the econometrics may have determined the results. The findings from the sensitivity analysis indicate that the results continue to hold even if extreme values are discarded, if more policy variables are considered, and if a number of potential selection problems are considered.

Table 2 Estimated effects of policy instruments on waste quantities by intended treatment (kg/adjusted population)

	Total household waste	Bin and bag waste for incineration	Food waste for biological treatment	Materials for recycling	Other treatment
Weight-based tariff					
- Immediate effect	-12.15	-3.38	-11.06*	-1.02	3.30
	(-0.46)	(-0.33)	(-1.95)	(-0.14)	(0.15)
- After 1 year	6.901	-2.50	-15.75**	12.87	12.29
	(0.19)	(-0.18)	(-2.05)	(0.93)	(0.39)
- After 2 years	12.83	-8.03	-17.74*	0.25	38.35
	(0.29)	(-0.44)	(-1.88)	(0.02)	(0.95)
- After 3 years	15.84	-16.54	-18.30*	2.89	47.79
	(0.33)	(-0.89)	(-1.71)	(0.16)	(1.10)
Separate food collection					
- Immediate effect	-11.10	-18.06**	11.35	6.23	-10.62
	(-0.45)	(-2.27)	(1.62)	(1.44)	(-0.48)
- After 1 year	28.07	-27.14**	16.28**	18.86**	20.07
	(1.23)	(-3.34)	(2.40)	(2.16)	(0.86
- After 2 years	7.790	-38.49**	21.53**	24.78**	-0.03
	(0.32)	(-4.29)	(3.10)	(2.11)	(-0.00)
- After 3 years	3.920	-40.34**	25.15**	49.39**	-30.28
	(0.16)	(-3.74)	(3.19)	(3.91)	(-1.17)
Background variables	Yes	Yes	Yes	Yes	Yes
N	563	563	563	563	563

Note: * p < 0.10; ** p < 0.05. Only data for 2011–2014 are used, as there are not enough data on waste quantities for years prior to those. Standard deviations are clustered at the municipality level.

Table 3 Estimated effects of policy instruments on collected quantities of different types of waste (kg/adjusted population)

	Bin and bag waste	Bulky waste	Paper and packaging waste	Hazardous waste
Weight-based tariff				
- Immediate effect	-13.01**	-3.95	6.71**	1.13
	(-2.03)	(-0.22)	(2.23)	(0.97)
- After 1 year	-22.16**	5.60	4.21	2.28
	(-2.71)	(0.32)	(1.35)	(1.27)
- After 2 years	-22.10**	-0.09	0.90	1.41
	(-2.24)	(-0.00)	(0.19)	(0.65)
- After 3 years	-40.39**	18.14	-4.44	1.61
	(-4.70)	(0.93)	(-0.58)	(0.75)
Separate food collection				
- Immediate effect	-10.82**	11.93	4.825*	-1.29
	(-2.32)	(0.82)	(1.87)	(-1.37)
- After 1 year	-16.58**	36.41*	7.77**	-1.44
	(-2.84)	(1.67)	(2.20)	(-1.43)
- After 2 years	-19.11**	27.37	9.308**	-3.22**
	(-3.75)	(1.62)	(2.66)	(-2.60)
- After 3 years	-19.77**	38.92*	9.386**	-2.87**
	(-3.32)	(1.79)	(2.61)	(-2.20)
Background variables	Yes	Yes	Yes	Yes
N	1,123	1,123	1,123	1,123

Note: * p < 0.10; ** p < 0.05. Standard deviations are clustered at the municipality level.

In a sensitivity check, we tried replacing the data on paper and packaging waste from the Swedish Waste Management Association with corresponding data from FTI, the national company tasked with collecting paper and packaging waste. The main impact on the results was that, when the FTI data were used, the effect of weight-based tariffs on the collected quantities of paper and packaging waste appeared to be more persistent.

8 Discussion

The first step in the EU waste management hierarchy is to prevent waste, but neither of the policy instruments studied in this paper had a distinct effect on the total amount of collected municipal waste. However, subsequent steps in the waste management hierarchy – reuse, materials recycling (including biological recycling), energy recovery (mainly through incineration), and disposal of waste – show material recycling and biological recycling are prioritised over incineration for energy recovery. The study showed that the system of collecting food waste separately unambiguously reduced the amount of bin and bag waste intended for incineration (i.e. energy recovery), while it simultaneously increased the amount of food waste intended for recycling as well as biological waste intended for recycling. With respect to weight-based waste tariffs, we saw no significant effect on either the collection of bin and bag waste for incineration, or on the quantities of waste intended for recycling, but the weight-based tariffs reduced the amount of food waste for biological treatment.

Based on these results, we can conclude that, if the goal is to reduce incineration on the one hand and to increase recycling and biological recovery on the other, then it seems that the separate collection of food waste is a successful policy instrument. In this regard, the weight-based tariff does not perform as well. This difference in effect between the two instruments might seem surprising. In a way, the instruments can be seen as two sides of the same coin – where the weight-based waste management tariff effectively acts as a tax or penalty on the unsorted waste, while the collection of food waste, by making sorting less time consuming, effectively acts as a subsidy for sorted waste. The direct incentive effects should be similar, therefore. One explanation of the difference in effect between the two policy instruments could be that the collection of food waste sends a stronger signal about what is considered to be environmentally responsible behaviour, and that the waste separation induced by this system has a self-reinforcing effect. This could explain why the collection of food waste affects the amount of waste destined for recycling, despite the fact that the subsidy only actually affects food waste.

It needs to be borne in mind that this study investigated whether the weight-based tariff system itself had an effect on the various waste streams, rather than whether or how the size of the tariff affected the various waste streams. For example, an increased differentiation between the weight-based fee for bins and bags and a weight-based tax on food waste could lead to increased reallocation from higher-tariff mixed waste to lower-tariff sorted waste. This is left for future studies on the subject.

Furthermore, as noted earlier in Section 5, the study explored the effect of the treatment on how the waste was intended to be treated, not how it was actually treated. This came about because we did not have access to data on the actual treatment of waste at municipal level. This is certainly a fruitful area of investigation for future studies.

Since the separate collection of food waste is based on an intervention which involves a simplified sorting system, this separate collection should not lead to a behaviour change where households deliberately increase the amounts of wrongly sorted waste or illegal dumping. There is a greater risk that a weight-based waste tariff may create incentives for this.

That a policy instrument has an effect does not necessarily mean that it is cost-effective. Of course, generally speaking, economic instruments are usually cost-effective: agents take action until their marginal cost of taking action is equal to their marginal cost of not doing so. Earlier herein it was argued that a weight-based waste tariff could be seen as a tax on not sorting waste, and that the separate collection of food waste could be seen as an implicit subsidy for waste separation. Both policy instruments will lead households to sort their waste up to the point where their perceived marginal cost of doing so is equal to the perceived marginal cost of not doing so. In addition to this, however, our results suggest that collecting food waste separately also has indirect effects on household waste production: recycling is seen as beneficial and, thus, influences what households do in order to maintain a positive self-image. If this interpretation is correct, by strengthening the self-image effects of recycling, the separate collection of food waste also reduces the perceived net cost of recycling for many households, making the overall social cost of recycling lower than it would otherwise have been. Reducing perceived costs in this fashion would appear

to be a highly cost-effective means of reducing the overall costs of waste management policies, and is a topic that deserves further study.

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