Chapter 5

Weight-based pricing in the collection of household waste: the Oostzaan case

5.1 Introduction

The most common way to charge households for household waste collection is still the fixed fees schedule. Clearly, such an pricing scheme hardly provides an incentive to reduce the generation of waste. Whether or not the fee depends on the household size or other household characteristics, the household faces no extra costs when it generates an extra amount of waste. In other words, when a household reduces its amount of waste, it is not rewarded for this reduction. With the unit-based pricing programs, households are rewarded financially for waste reduction.

Only a few papers reported on the implementation of unit-based pricing programs. One of the papers is Fullerton and Kinnaman (1996), who analyzed the effects of a volume-based pricing program in Charlottesville, Virginia, United States, in which household waste was charged per bag. They found that the program had a substantial effect on the volume but little effect on the weight of waste – the weight per bag – increased considerably. Moreover, the weight of recyclable materials increased. Fullerton and Kinnaman argued that a weight-based pricing program is likely to be more effective.[1]

[1] In some cases a policy aimed at reducing volume rather than weight may be more appropriate, for example if after collection waste is stored on landfill sites; see e.g. *The Economist*, June 7th 1997, p.92 and June 28th 1997, p.4. In the Netherlands, however, storing waste on landfilles is prohibited since 1996. Non-recyclable waste is now incinerated after

This Chapter investigates the implementation of a weight-based pricing program for the collection of household waste. We analyze a comprehensive data set on households that faced weight-based pricing. We estimate the price effects as well as the effects of household characteristics on the amount of both compostable and non-recyclable household waste. The data set provides detailed information on all households in Oostzaan, the first municipality in the Netherlands to implement weight-based pricing. In the first year after the introduction the amount of waste per household declined by 30 percent (see table 5.1). The decline continued in the second year, and then stabilized in the third year after introduction.

Table 5.1: *Annual amounts of waste in Oostzaan and percentual changes in the period* $1992 - 1996$

	1992-93	1993-94	1994-95	1995-96
total waste (in 1000 kilograms)	1154.6	825.9	724.4	725.9
change (percentage)		-28.5	-12.3	+0.2
waste per household in kilograms	384.7	270.7	230.0	223.0
change (percentage)		-29.6	-15.0	-3.0

The columns apply to the period July, 1 up to June, 30 of the next year.

In addition to being weight-based rather than volume-based, the Oostzaan case has a number of advantages over earlier studies. First of all, the survey consists of weekly data on the weight of two types of waste. Secondly, with data on 4,080 addresses the present survey is much larger than the surveys used before. Thirdly, the survey has a panel structure in which the addresses are observed for a period of 42 months. The panel data allow us to take account of unobserved individual effects, and to analyze the effects of household characteristics on the amounts of waste. Moreover, it allows us to estimate long-run price effects.

The outline of this Chapter is as follows. Section 5.2 summarizes the literature on volume-based and weight-based pricing programs in the collection of household waste. This section discusses the role of the household production framework in household waste collection and the empirical findings in the literature. In section 5.3, the Oostzaan case is described as well as the data set. Section 5.4 presents the econometric specification and the estimation results. In section 5.5 some topics related to weight-based pricing in Oostzaan – illegal dumping, recycling, and implementation costs – are discussed. Section 5.6 concludes.

collection, in which case weight is the more relevant dimension.

5.2 Literature

The economic literature on household waste collection can be divided into three classes. The first class – mainly theoretical – focuses on the collection of household waste within the framework of household production (see subsection 5.2.1). The second class – mainly empirical – focuses on consumer responses to various pricing schemes (see subsection 5.2.2). Finally, the third class – mainly theoretical – uses more comprehensive models in which the behavior of governments, firms and consumers are analyzed simultaneously (see subsection 5.2.3).

5.2.1 Household production framework

Households waste is a by-product of household production processes and therefore it can be analyzed naturally within the framework of the household production (cf. Wertz, 1976; Hong *et al.*, 1993; Morris and Holthausen, 1994; and Fullerton and Kinnaman, 1995). Particularly, the consumer decision with respect to disposal options is merely a trade-off between costs and time requirements given the disposal options offered. Generally, recycling implies more time inputs but less costs than conventional disposal. A consumer chooses to recycle if the marginal benefits of recycling – the reduction of collection costs – are higher than the costs of extra time inputs.[2]

Morris and Holthausen (1994) developed a household production model of waste management including the consumer decision of consumption goods purchase, the household production processing and the disposal options. A consumer considers two options with respect to waste disposal.[3] He can either dispose waste in a conventional way or he can recycle it.[4] Both options differ in costs and the time spent. Conventional disposal is more expensive than recycling, since recycling is subsidized, but it requires less time. The subsidy may differ across recyclable materials, as it depends on the nature of the material, the total supply of a particular recyclable material, and the consumer's effort to recycle. The Morris-Holthausen model includes two specific features. The first specific feature is the inclusion of the amount of recycled materials in the utility function. This implies that consumption goods can be purchased for both

[2] Here, we assume that households are charged per unit of waste collection.

[3] In the economic literature illegal dumping is also mentioned as a waste diposal option. Here, we ignore this option because our aim is to discuss the role of household waste collection within the household production framework .

[4] In the coventional way household waste is collected at the curb and either stored in landfills or incinerated.

their utility in consumption and the opportunity they provide for recycling in their own right (see Morris and Holthausen, 1994, p. 221). Secondly, from the first order conditions of the model the commodity prices include the time and purchased inputs in producing the inputs as well as the additional costs of time and purchased inputs associated with both disposal options.

Suppose a consumer maximizes its utility function

$$U(X, L, R),$$

which is a function of commodities, $X = (x_1, .., x_n)$, leisure (L) and recyclable materials (R). When the consumer produces commodities, it generates waste at the same time. The Morris-Holthausen model distinguishes four types of production functions: commodities (X), total amount of waste (W), conventional waste (G) and recyclable materials (R). The production functions for material i are

$$\begin{aligned} x_i &= x_i(H_{ix}, Y). \\ W_i &= x_i z_i f_i(H_{iw}, Y), \\ G_i &= g_i(H_{ig}, Y), \quad \text{and} \\ R_i &= h_i(H_{ir}, W_i, Y). \end{aligned}$$

The inputs of the commodity production function are time requirements (H_{ix}) and the bundle of the consumption goods (Y). The total amount of waste is a fixed proportion (z_i) of commodities produced and a reduction effort function. This reduction effort is reflected by f_i which is a function of time spent on waste disposal and the total bundle of consumption goods. The reduction effort is unity when a consumer does not spend any time on the waste disposal and he does not purchase consumption goods. If a household spends time on reducing its amount of waste then f_i will decline and as a result W_i will decline. Note that both the fixed proportion and the reduction effort function may differ across materials.

Furthermore, the model distinguishes production functions for two types of waste disposal options, namely conventional waste disposal and recycling. The inputs of the conventional waste production function are a time requirement (H_{ig}) and the bundle of consumption goods. The conventional waste production is increasing in time and consumption goods. The recyclable material production function depends on a time requirement (H_{ir}) the bundle of consumption goods, and the total amount of waste of material i. The recycling production function is increasing in the time spent on recycling, the total amount of waste and total amount of consumption. The consumer considers a time budget constraint and an income budget constraint:

$$
\begin{aligned}
T &= B + H + L, \\
\omega B &= \rho Y + cW - \sum_{i=1}^{n} s_i R_i + F, \\
\text{with} \quad R &= \sum_{i=1}^{n} R_i \; ; \qquad W = \sum_{i=1}^{n} W_i \qquad \text{and} \\
H &= \sum_{i=1}^{n} H_{ix} + H_{iw} + H_{ir} + H_{ig},
\end{aligned}
$$

where B is the time spent on work in the market, ω is the wage rate, ρ are the prices vector of consumption goods, c is the price of waste collection and s_i is the refund of recyclable material i, and F is the fixed fees. A consumer receives a subsidy s_i whenever he recycles one unit of material i.[5] As mentioned above, the subsidy differs across recyclable materials.[6]

According to the Morris-Holthausen model, a consumer has two options to reduce his amount of waste, namely reducing the total amount of waste and recycling. As to the first option, a consumer gains from reducing the total amount of waste as he avoids collection costs and the costs of producing conventional waste (less time and consumption goods). There are three types of costs associated with the reduction of the total amount of waste. First, there are the direct costs of the reduction effort. Secondly, the reduction of the total amount of waste makes it more difficult to produce recyclable materials, and finally, less recycling implies a monetarized loss in utility resulting from a larger effort to produce recyclable materials. If the sum of collection costs and the full cost of producing one unit of conventional waste is positive, consumers have an incentive to reduce their amount of waste. The effect is offset to some extent if the consumer has an easy recycling opportunity.

[5] In the Netherlands, households may haul recyclable materials such as recyclable paper and glass to drop-off centers and avoid any collection costs. In those cases, s, and c are both zero. In the case of recycling, the time input, however, is substantially larger than in the conventional disposal case.

[6] Morris and Holthausen assumed the Leontieff production technology for both the production functions of commodities and the amount of conventional waste respectively. As a consequence, the full cost of producing one unit of good i and are easily calculated. Furthermore, they rewrote the waste production function and recycling production function as an inverse cost function with the minimum cost of a given level of production as the parameter. The minimum costs include the opportunity cost of time spent on production and the cost of consumption goods used as inputs. With these assumptions Morris and Holthausen presented the first-order conditions.

As to the latter option, a consumer gains form recycling in two ways. First, he avoids the collection costs, the cost of producing one unit of conventional waste and receives a subsidy. Secondly, he experiences a monetarized gain in utility due to the increasing recycling effort. An increase in the collection cost or subsidies would increase the production of recyclable materials. Also, an increase in the conventional waste production costs implies an increase in the production of recyclable materials.

Fullerton and Kinnaman (1995) applied a similar model of consumer behavior with respect to recycling materials and waste. In fact, their model is a special case of the Morris-Holthausen model. Fullerton and Kinnaman used three different assumptions. First, recyclable materials do not directly enter the utility function which implies that the activity recycling does not generate utility itself. Secondly, recyclable material production is a fixed proportion of time requirements. Finally, recycling is not subsidized but free of collection cost. They concluded that an increment of the collection tax may result in behavioral adjustments in two directions. First, the consumer may reduce its amount of waste by consuming less, and secondly it may adjust its recycling behavior (provided that the consumer is not an optimal recycler at the time).

Both models above clearly show the trade-off between time requirements and costs which a consumer deals with when managing its waste disposal. In both models the marginal costs of generating an additional amount of waste were explicitly assumed to be positive ($c > 0$). In practice, the fixed fees program is still widely used; hence the marginal costs are zero ($c = 0$).

5.2.2 Consumer behavior and household waste

Although weight-based pricing has not been analyzed with individual household data, there exist a number of empirical articles on volume-based pricing (cf. Fullerton and Kinnaman, 1996; Hong *et al.*, 1993; and Reschovsky and Stone, 1994). In these studies the price and income effect were analyzed as well as the recycling behavior.

Hong *et al.* (1993) analyzed a particular form of volume-based pricing with a survey of 2,298 households from Portland, Oregon, United States. Households signed a contract with the collector on a maximum number of containers to present per month. Up to this maximum, households pay \$12 per container, but for an extra container, households pay \$24 per container. Since price depends on quantity, the price per containers is endogenous. Hong *et al.* estimated the

Table 5.2: *Review of elasticities in volume-based pricing literature*

Study	Elasticities		
Area[a]; year	own-price	cross-price[b]	income
HOUSEHOLD SURVEYS			
Hong *et al.* (1993)	-0.03		0.049
Portland, Oregon; 1990			
Fullerton and Kinnaman (1996)	-0.226[c]		
Charlottesville, Virginia;1992	-0.058[d]	0.073[d]	
AGGREGATE MUNICIPALITY DATA			
Wertz (1976)	-0.25		0.242 to 0.279
Morris and Byrd (1990)	-0.26		
	-0.22		
Skumatz and Beckinrigde (1990)	-0.14		
EPA(1990)			
Perkasie PA		0.49	
Illion, NY		0.48	
Seattle; 1985-86		0.06	
Seattle; 1986-87		0.10	
Jenkins (1991)	-0.12		0.41

[a]All studies used United States data.
[b]The elasticity of the recyclable amount of waste with respect to the price of waste collected at the curb.
[c]based on volume of household waste.
[d]based on weight of household waste.

demand for containers contracted, correcting for the endogeneity of the price, and the participation in recycling activities. They found small responses with respect to changes in prices and income (see also table 5.2). Reschovsky and Stone (1994) surveyed 1,422 households around Itchaca, New York, who faced a variety of volume-based pricing and recycling rules. The probability of recycling each type of material is estimated as a function of these rules and of demographic characteristics. The authors concluded that curbside pickup of recyclable materials alone would increase recycling more than the implementation of volume-based pricing would do. Both articles used cross sections only.

The data of Fullerton and Kinnaman (1996), who analyzed the effects of introducing a price per bag in Charlottesville, Virginia, United States, were collected at two different points in time. Their survey consisted of 75 households which were observed twice for a period of two weeks. The first period of observation was before the new pricing was introduced, and the second period was three months after implementation. The results showed that the volume declined by 37 percent and the weight by 14 percent, while the weight-volume intensity increased with 31.7 percent. Moreover, the weight of recyclable materials increased with 15.7 percent. Their estimated price elasticity of the amount of household waste measured in kilograms was rather small, -0.058 (see also table 5.2).

Table 5.2 shows the price elasticities of the demand for household waste collection. Due to the nature of the data sets used, the long-run effects of particular pricing program have been ignored so far. If the result from the studies using household surveys are compared to those using aggregated data sets, the price elasticities are rather low.

5.2.3 Household waste management

The second class of articles analyzes more comprehensive of household waste management (for instance, see Jenkins 1991; Sigman, 1991; Fullerton and Kinnaman, 1995; Choe and Fraser, 1999; and Atri and Schellberg, 1995). Jenkins (1991) and Sigman (1991), for instance, built a theoretical general equilibrium model to determine the optimal fees for household waste collection. In their models, consumers had only two disposal options; garbage or recycling. The optimal (positive) fees for households waste collection equal the direct resource cost plus external environmental cost. In Fullerton and Kinnaman's (1995) model consumers have additional disposal options: illicit burning and dumping. The external environmental costs of these options are relatively high as compared to the other options, and it cannot be taxed directly. Fullerton and Kinnaman concluded that with these disposal options, the optimal fee structure is a deposit-refund system: a tax on all output combined with a rebate on proper disposal through either recycling or waste collection. In particular, household waste collection should be subsidized in order to prevent illicit burning and dumping which imply high external environmental cost. Similar results were obtained by Atri and Schellberg (1995) using a dynamic general equilibrium model.[7]

An alternative policy instruments for waste management, the 'recycled contents standard', was analyzed by Palmer and Walls (1997). This standard requires a certain fraction of the materials in the production of goods to be recyclable. Palmer and Walls concluded that this policy measure alone cannot lead to an optimal allocation of waste disposal and should be combined with

[7] Atri and Schellberg emphasized that collection taxes should differ across the groups of materials, since marginal costs of disposal differ across these groups.

taxes on the final output and other inputs. Choe and Fraser (1999) considered a model in which three agents interact: a firm, a household and a regulator. Four different types of waste were considered. The optimal policy combines an environmental tax, a household waste collection charge, and monitoring and fining illegal waste disposal.

In all these models, the price sensitivity of household demand for waste collection is a key parameter.

Our study fits into the second class of articles, and analyzes household behavior conditional on the institutional setting. We note that the potential endogeneity of choosing the weight-based pricing policy is not an issue here. Oostzaan was the first of 600 Dutch municipalities to implement such a program. The pioneering role of Oostzaan is related to its exceptional position in the political spectrum.[8]

5.3 The Oostzaan case

Oostzaan is a countryside village situated 15 kilometers North from Amsterdam.[9] In 1992 the city council agreed to introduce weight-based pricing. As from July 1993, however, the household waste was weighed when collected and households received a *pro forma* bill with the virtual amount representing the expenses of collecting their current amount of household waste. During the period July to September 1993, households still paid fixed charges, as they did prior to July 1993.

It is important to understand how the waste collection in Oostzaan is organized. The weight-based pricing only applies to the curbside collection of waste. Two types of waste are collected separately: compostable waste (GFT) and non-recyclable (or solid) waste (which is also referred to as rest waste, RST).[10] For each type of waste a household has a separate container. About 7 percent of the households, however, share a GFT container with one or more other households.

Households have the opportunity to dispose recyclable materials, small chemical waste and large volume units differently. For instance, large volume

[8] The majority in the city council of Oostzaan is environmentally very engaged. The largest political party is *Groen Links* (Green Left), which is a strongly environmentally orientated political party in the Netherlands. Nationwide, *Groen Links* received only 3.5 percent of the votes in the parliamentary elections of 1994.

[9] In 1996, the municipality counted 3,309 househoulds. Approximately 10 percent of the dwelling stock are apartment buildings, while more than 80 percent of the dwellings have a garden.

[10] Compostable waste includes organic waste and yardwaste. It is usually called GFT which is the Dutch abbreviation for vegetables, fruit and yardwaste.

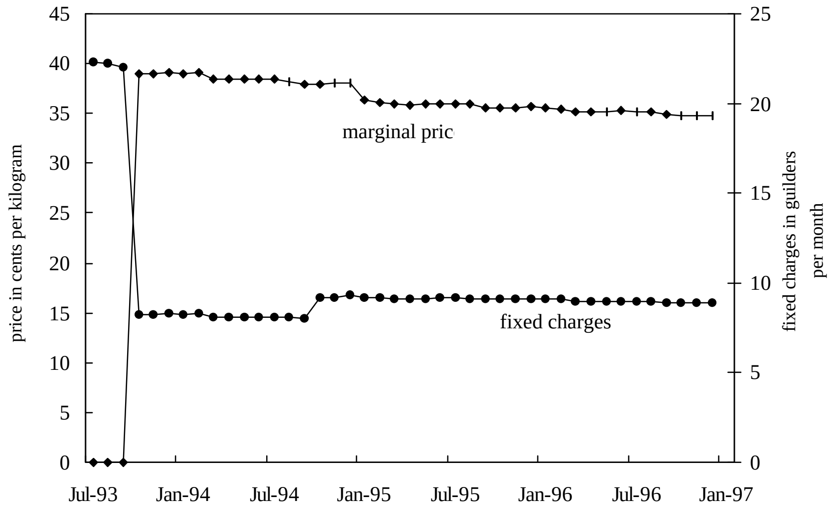

Figure 5.1: *Real marginal prices (in cents per kilogram) and fixed charges (in guilders per month) for household waste collection in Oostzaan during the period July* 1993 *to December* 1996*.*

units of waste, not fitting in the container, can be collected after making an appointment with the municipality. This collection is not free of charges. For recyclable paper there is a free curbside collection program organized by local sports clubs. This program already existed before the introduction of weight-based pricing.[11] A number of recyclable materials, such as glass, small chemical waste, textiles and tins can be hauled to special containers placed at various locations in the municipality. The use of these containers is free of charge apart from the time input that is required). Furthermore, the municipality also stimulates home composting by subsidizing the purchase of home compost containers.

The municipality has contracted a private company for the collection of household waste.[12] During the period of the survey, the company used one single truck with a weighing appliance for collection.[13] All containers have

[11] With this activity these clubs earn some extra money. The local authority subsidizes the collection of paper by covering the expenses of collection and by an extra amount of 5 cents per kilogram of recyclable paper collected.

[12] Browning-Ferris Industries (BFI), a company for waste collection that operates worldwide.

[13] The weighing appliance has been calibrated by the Institute for Metrology and Technology (NMI).

Table 5.3: *Annual expenses in* 1990 *guilders on household waste in Oostzaan and neighboring municipalities in the period* 1994 *to* 1996.

	1994			1995			1996		
	household size			household size			household size		
	1	2	>2	1	2	>2	1	2	>2
municipality									
Amsterdam	-	-	-	142	284	284	-	-	-
Beemster	-	-	-	263	395	395	279	393	393
Landsmeer	-	-	-	232	284	337	233	287	341
Oostzaan	299	299	299	-	-	-	-	-	-
Oostzaan[a]	211	237	283	221	240	283	217	238	287
Purmerend	346	346	346	360	360	360	354	354	354
Waterland	230	345	379	226	339	372	222	333	366
Wormerland	-	-	-	296	296	296	291	291	291
Zaanstad	301	301	301	351	351	351	344	344	344

[a]These expenses are based on the average annual weights of household waste in the Oostzaan sample.

a chip with a unique code which identifies a particular address. During the collection, the contents of the container is weighed and the chip is red, and both are registered by a computer. With this information the municipality can charge households.[14]

The weight-based pricing schedule

Before October 1993, the marginal prices for compostable and non-recyclable waste were zero, as households paid only fixed charges. From October 1993, the nominal marginal price was 43 cents per kilogram. The fixed fees were reduced simultaneously from approximately 25 to 10 guilders per household per month. On January 1, 1995, the price per kilogram was decreased with 2 cents. Figure 5.1 shows the development of marginal prices and fixed charges in real terms. Households with joint GFT containers have a zero marginal prices for their GFT waste but they do have to pay extra fixed charges. For non-recyclable waste, they face positive marginal price, since they do have a personal container for non-recyclable waste. The price for large volume units was constant: 15 guilders per cubic meter.[15]

[14]The joint GFT containers also have a unique chip code. This code is the same for all households using the joint GFT container.

[15]The municipality can be regarded as a non-profit organization with a cost minimizing objective. The main reason for the city council to adjust prices is either to avoid uncovered expenses or positive profits.

From an environmental perspective weight-based pricing is favored over other pricing schemes as it represents the *the polluter pays principle.* From a social perspective, however, we may raise the question whether or not households are financially worse off due to the introduction of the weight-based pricing[16]. Table 5.3 shows the development in the annual expenses on the collection of household waste in Oostzaan and its surrounding municipalities. The development in the expenses in the surrounding municipalities can be interpreted as the development of expenses in Oostzaan if the weight-based pricing would not have been introduced.[17] In a few municipalities the annual expenses depend on household size, and we therefore distinguished three household size categories.

On average, Oostzaan households seem to be better off in financial terms than households in the neighboring municipalities, since the implementation of the weight-based pricing. In Oostzaan the average expenses declined, while in the neighboring municipalities the expenses increased rapidly. Although we took account of the household size, the expenses in Oostzaan may be somewhat misleading. In particular, given the household size, households presenting large waste amounts will be worse off after the introduction of the weight-based pricing program, while households presenting little amounts will be better off.

Data

The Oostzaan survey consists of three parts: a survey on the demographic characteristics of households, the weighing data on GFT and the weighing data on RST. The demographic survey consists of 4,080 addresses. It includes variables on household composition, mutations in household composition,[18] the type of dwelling, and container chip numbers. It comprises the period July 1993 to September 1997. Mutations of household size during this period and the variable household size have been obtained from the Population Register of Oostzaan. Both types of weighing data are registered during the collection of household waste in the period July 1993 to December 1996. Due to the weighing process, measurement errors are likely to be negligible.

For the analysis, 1,167 addresses have been dropped, mainly for the following

[16] Since we are only focusing on costs and not on preferences, we cannot analyze the welfare implications of the weight-based pricing program.

[17] In none of the neighboring municipalities the pricing program changed during the period considered.

[18] We do not have information on the places households move to. In particular, if a household moves within Oostzaan, we do not know the new address. All households that move to an address in Oostzaan during the sample period are therefore treated as new households.

reasons. First of all, a number of addresses are not used as living accommodations. Secondly, in a number of cases, the correct household size cannot be reconstructed with the available information. Thirdly, since we aim to estimate demand equations including individual effects we restrict our sample to households with at least two periods of observation. The resulting address sample consists of 2,913 different addresses. Due to movements of households, we often observe more than one household at the same address during the period July 1993 to December 1996. As a result, we have data on 3,459 households.

The number of periods a household is observed varies between 2 and 42, with an average of 37 observations per household. We thus use an unbalanced panel. The total number of observation $N_T = \sum_{i=1}^{N} T_i = 127,851$, where $i = 1,..,N$ refers to the households and T_i is the number of observations for household i. Table 5.4 shows summary statistics for the final sample. Table 3 shows the development of the average amounts per households for nine different types of waste.

In our sample the average weight is 9.9 kilograms per month for compostable waste and 18.2 kilograms per month for non-recyclable waste. Note that in the case of compostable waste we do not always observe the actual amount of waste, because for households sharing their GFT container we only observe the total weight per month for all households sharing the container. In those cases we calculate the average weight per household per month by dividing the total monthly amount of waste of the joint GFT container by the number of households.

In the next section we discuss the reduced-form demand equations for compostable and non-recyclable waste presented for collection and the estimation results.

Table 5.4: *Summary statistics of the Oostzaan sample*

Variable description	mean	standard deviation	minimum	maximum
HOUSEHOLD VARIABLES				
Household size	2.54	1.18	1	9
Age of oldest household member	50.6	16.1	18	96
Share of women in household	0.519	0.261	0	1
0-2 years	0.107	0.309	0	1
2-6 years	0.120	0.325	0	1
6-12 years	0.127	0.333	0	1
12-18 years	0.121	0.327	0	1
AMOUNTS OF WASTE				
Compostable waste in kilograms	9.94	16.49	0	298.5
Non-recyclable waste in kilograms	18.15	20.30	0	262.5
REAL MARGINAL PRICES IN CT/KG				
Non-recyclable waste	33.90	10.18	0	39.45
Compostable waste	31.64	12.95	0	39.45
FIXED CHARGES IN DFL. PER MONTH				
Non-recyclable waste	9.91	3.72	8.13	22.32
Compostable waste	8.85	3.21	8.13	22.32
TIME VARIABLES				
February	0.07	0.26	0	1
March	0.07	0.26	0	1
April	0.07	0.26	0	1
May	0.07	0.26	0	1
June	0.07	0.26	0	1
July	0.09	0.29	0	1
August	0.10	0.29	0	1
September	0.10	0.29	0	1
October	0.09	0.29	0	1
November	0.09	0.29	0	1
December	0.09	0.29	0	1
1994	0.28	0.45	0	1
1995	0.29	0.45	0	1
1996	0.29	0.46	0	1

continues on the next page

Table 5.4: *Summary statistics of the Oostzaan sample continued*

Variable description	mean	standard deviation	minimum	maximum
TYPE OF DWELLING				
Won A (semi-detached)	0.14	0.35	0	1
Won B (dwelling for the elderly)	0.02	0.15	0	1
Won C (flat ground level)	0.03	0.18	0	1
Won D (flat higher floor)	0.06	0.23	0	1
Won E (houseboat)	0.01	0.08	0	1
Won F (detached)	0.17	0.38	0	1
Won G (part of a company)	0.01	0.12	0	1
Won H (caravan)	0.002	0.04	0	1
Won I (summerhouse)	0.0003	0.02	0	1
Temperature[a]	13.8	6.7	1.6	27.1
Diftar (1 if weight-based pricing)	0.919	0.273	0	1
Joint container for GFT waste	0.068	0.252	0	1

[a]The temperature data are the highest daily temperatures in the nearest measurement station of Oostzaan. On the basis of daily observations we calculated monthly averages for the period July 1993 to December 1996. Source: Royal Netherlands Institute for Meteorology (KNMI).

5.4 Econometric analysis

5.4.1 Specifications

We will estimate reduced-from demand equations for waste collection. Our approach largely follows the work of Fullerton and Kinnaman (1994, 1996) with two major differences. First, we distinguish two types of waste: compostable waste (GFT) and non-recyclable waste (RST) and estimate separate equations for each type. Secondly, we consider a much longer period of time. This allows us to include a lagged dependent variable in the specification in order to determine long-run price effects.

The general specification is

$$q_{it} = \alpha_i + \beta P_t + \gamma(y_{it} - F_{it}) + \delta' X_{it} + \phi q_{it-1} + \epsilon_{it}, \tag{5.1}$$

where q_{it} is the weight of waste collected for household i in period t; P_t and F_{it} are the marginal price and the fixed charges of time period respectively, and y_{it} is household income. X_{it} is a vector of other household characteristics and ϵ_{it} is the error term; α_i, β, γ, δ and ϕ are parameters to be estimated. The panel data allows us to include a household specific constant term which includes heterogenous effects which are not observed. The data set does not contain direct information on household income. Therefore, the term $\gamma(y_{it} - F_{it})$ is absorbed in the household specific terms $\alpha_i + \epsilon_{it}$.[19]

We will estimate four specifications with different assumptions. We therefore estimate two Fixed Effects specifications as in (5.1).[20] We estimate a specification with and without a lagged dependent variables (i.e. $\phi = 0$). Both the Fixed Effects specifications are estimated with the Least Squares Dummy Variable (LSDV) method. If the lagged dependent variable is included, the LSDV estimator of the coefficient of this variable is inconsistent. However, since we use up to 42 time observations per household, the asymptotic bias is rather small (see Hsiao, 1986, pp.74-75).

Given our panel data set, the Fixed Effects specifications seem the most appropriate specifications to estimate. However, our data set includes variables which are constant during the period considered, so that these variables cannot be included in a Fixed Effects specification. Hence, we estimate two alternative specifications. First, we estimate a specification with a constant household specific term ($\alpha_i = \alpha$), and no lagged dependent variable ($\phi = 0$). This specification allows us to include explanatory variables which show no variation for a particular household (such as type of dwelling). This specification is estimated with Ordinary Least Squares (OLS). Secondly, households do not present waste for collection continuously (during holidays for instance). This means that the dependent variable is likely to be censored. In that case, the OLS estimation results will be biased (cf. Maddala, 1983). The specification of the demand for household waste collection is a Tobit type of specification:

$$q_{it} = \begin{cases} q^*_{it}, & \text{if } q_{it} \geq 0 \text{ and} \\ 0, & \text{otherwise,} \end{cases} \tag{5.2}$$

and

$$q^*_{it} = \alpha + \beta P_t + \delta' X_{it} + \epsilon_{it}. \tag{5.3}$$

As in the first specification, we assume that $\alpha_i = \alpha$ and $\phi = 0$. This specification is estimated with the Maximum Likelihood Estimation (MLE) method (see also Maddala, 1983, for instance).[21]

[19] Theoretically, the parameter γ could be estimated on the basis of the variation in the fixed fees F_{it} alone. However, this turned out not to be feasible due to very high negative correlation between the marginal price P_t and the fixed fees F_{it} in the data set; cf. figure 5.1.

[20] A Hausman specification test indicated the rejection of the random effects model.

[21] An underlying assumption in both specifications above is that the observations in the

The next section presents the estimation results of the four specifications.

5.4.2 Estimation results

Fixed effects estimation

We estimated two Fixed Effects (FE) specifications. The major advantage of the FE estimation is that unobserved heterogeneous individual effects can be taken into account. In general, the use of panel data surveys improves the accuracy of the price coefficients estimates as the unobserved effects are taken into account for each individual household. In our case the income variable is included in the individual effect as well. Due to the nature of our data we can include a lagged dependent variable in order to estimate the long-run price effect.

Table 5.5 shows the Least Squares Dummy Variable estimation results for the Fixed Effects specifications. The first and second column present the results of the specification without a lagged dependent variable. The marginal price coefficients are -0.374 and -0.273 for compostable waste and non-recyclable waste respectively. The price response of households to price changes is larger for compostable waste collection, which corresponds to the earlier findings with the other specifications. This is likely to be related to the fact that for compostable waste an alternative for curbside collection – home composting – is more easily available than for non-recyclable waste.

In the years 1994, 1995, and 1996 the amounts of waste were significantly lower than before. These effect are additional to the price effects, as prices have been included as an explanatory variable. The decrease seems to be permanent for GFT; for RST the decrease dissipated in recent years. One possible explanation is that the introduction of weight-based pricing and the extensive public debate that preceded it temporarily boosted environmental awareness in Oostzaan. A permanent effect may have been that GFT is now home composted rather than put at the curb. Another explanation is that RST waste is likely to be much more sensitive to increase in household income than RST (average disposable income increased by approximately 8 percent during the sample period). The amount of GFT is primarily determined by the garden area of the household (which does not change for a given address), and by the amount of food, a necessary good with a low income elasticity.

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data set are independent. In our panel data sample this assumption is likely to be violated. When this dependency is ignored, the estimates of the coefficients are likely to be biased, (see Hsiao, 1986, pp.5-8).

Table 5.5: *Least-Squares Dummy-Variables estimation results*

Variables	LSDV		LSDV[a]	
	GFT	RST	GFT	RST
marginal price	-0.374 (69.95)	-0.273 (45.35)	-0.329 (57.48)	-0.135 (21.65)
lagged dep. variable			0.203 (75.16)	0.222 (82.68)
two persons	1.344 (5.046)	2.431 (8.095)	2.010 (9.235)	1.567 (5.419)
three persons	2.367 (7.331)	6.477 (17.79)	3.007 (10.97)	4.566 (13.03)
four persons	3.066 (8.108)	8.031 (18.83)	3.952 (12.45)	5.887 (14.36)
more than four	4.538 (8.583)	11.799 (19.79)	4.647 (10.29)	8.806 (15.39)
age	-0.616 (3.870)	-1.873 (10.43)	0.061 (1.077)	-0.964 (5.590)
age squared	0.006 (5.418)	0.010 (8.459)	-0.0003 (0.528)	0.003 (2.145)
share of females	0.699 (1.476)	2.588 (4.849)	1.362 (3.715)	1.796 (3.499)
Children present				
0-2 years	1.119 (3.257)	3.209 (8.285)	1.489 (5.339)	2.181 (5.901)
2-6 years	0.263 (1.010)	-0.841 (2.863)	0.391 (1.722)	-0.536 (1.909)
6-12 years	0.583 (2.118)	-0.566 (1.824)	0558 (2.317)	-0.471 (1.604)
12-18 years	0.110 (0.431)	0.063 (0.219)	0.270 (1.155)	
temperature	0.323 (31.69)	0.242 (21.04)	0.299 (30.14)	0.189 (17.48)
1994	-4.044 (21.05)	-2.366 (10.92)	-3.050 (20.26)	-0.882 (4.239)
1995	-5.411 (19.69)	-1.500 (4.839)	-4.262 (29.09)	-0.144 (0.487)
1996	-5.785 (15.43)	-0.198 (0.468)	-4.483 (30.76)	1.134 (2.819)
second quarter	0.561 (3.760)	-0.937 (5.569)	0.071 (0.499)	-0.735 (4.747)
third quarter	-2.769 (14.01)	-3.194 (14.32)	-3.120 (17.25)	-2.594 (12.34)
fourth quarter	-0.908 (6.507)	-0.392 (2.489)	-1.472 (13.97)	-0.223 (1.504)
Adjusted R^2	0.46	0.55	0.48	0.59
$F\text{-}[N;N_T-(N+k)-1]$	32.73	45.78	33.54	52.05
N	3,459	3,459	3,437	3,437
N_T	127,581	127,581	124,100	124,100

[a] This specification includes the lagged dependent variable as an explanatory variable. As a consequence, the first observation of all household is excluded from the regression. Households with less than three observations are excluded as well.

A two-persons household produces 1.3 kilograms more GFT and 2.4 kilograms RST than a single-person household. The share of women significantly increases the amount of RST waste produced. This is probably related to the relative low labor force participation rate of women in the Netherlands: women are at home much more than men. An additional infant increases the amount of RST waste with 3 kilogram per month. Apparently, even in Oostzaan with an above average environmental concern, cloth diapers have not fully replaced disposable diapers. The temperature and second quarter have a positive effect on the amount of GFT waste presented. Both effects reflect increased yard maintenance. The third quarter show negative effects for both types of waste, which is likely to be a holiday effect; third holiday includes the summer school holidays.

The third and fourth column of table 5.5 present the results of the specification including a lagged dependent variable.[22] The marginal price coefficients are -0.329 and -0.135 for GFT and RST waste respectively, somewhat lower than the previous estimates. The lagged dependent variable coefficient is 0.2 (with high t-values) for both types of waste. This implies that the long-run elasticities are larger than the short-run elasticities; -1.39 and -0.34 for GFT waste and RST waste respectively; see also table 5.7.

In the period 1994 to 1996 the amounts of GFT waste are significantly lower than before even if the lagged amounts of GFT waste as well as prices have been included as an explanatory variable. This results supports the home composting explanation of the permanent GFT reduction as obtained from our earlier findings. In the case of RST waste we found an autonomous increase in recent years. This results supports the explanation that RST is rather insensitive to prices change but much more to changes in household income.

[22] One variable was excluded from the regression equation due to multicollinearity in the explanatory variables.

Table 5.5: *OLS and Tobit estimation results (absolute t-values in parentheses)*

	OLS		Tobit	
Variable	GFT	RST	GFT	RST
Intercept	17.285 (31.28)	29.445 (42.74)	2.760 (2.302)	25.413 (27.72)
Two persons	3.152 (24.75)	4.141 (26.49)	7.3005 (25.74)	6.619 (31.32)
Three persons	3.661 (22.81)	7.975 (40.51)	8.022 (22.63)	11.457 (43.50)
Four persons	6.922 (36.78)	10.613 (46.00)	14.565 (35.64)	15.369 (50.16)
More than four persons	6.417 (23.74)	12.659 (38.27)	12.219 (20.98)	17.337 (39.85)
Age	0.065 (3.419)	-0.159 (6.883)	0.155 (3.774)	-0.206 (6.655)
Age squared	-0.0008 (4.311)	0.0003 (1.263)	-0.002 (4.563)	0.0007 (2.530)
Share of females	1.661 (9.586)	2.456 (11.59)	5.870 (15.43)	4.497 (15.68)
Children present				
0–2 years	1.093 (6.547)	6.169 (30.20)	2.709 (7.748)	6.676 (24.96)
2–6 years	-0.891 (5.450)	1.563 (7.818)	-1.921 (5.556)	1.205 (4.605)
6–12 years	0.630 (3.970)	-0.186 (0.957)	1.569 (4.732)	-0.135 (0.532)
12–18 years	0.219 (1.325)	1.017 (5.037)	0.251 (0.725)	0.848 (3.209)
Marginal price	-0.320 (53.62)	-0.282 (32.85)	-0.577 (47.73)	-0.319 (28.44)
(joint GFT container)		-0.148 (6.548)		-0.195 (6.536)
Temperature	0.239 (9.288)	0.206 (6.537)	0.707 (12.54)	0.265 (6.329)
Time variables				
February	-0.570 (2.473)	-4.396 (15.59)	-1.360 (2.575)	-5.600 (14.93)
March	1.374 (5.541)	-3.200 (10.56)	3.409 (6.199)	-3.852 (9.585)
April	1.727 (5.448)	-3.864 (9.951)	3.439 (4.951)	-4.751 (9.229)
May	1.374 (3.713)	-0.447 (0.986)	1.963 (2.426)	-0.579 (0.965)
June	1.911 (4.409)	-5.476 (10.31)	2.606 (2.759)	-6.681 (9.481)
July	-1.900 (3.589)	-4.052 (6.227)	-5.438 (4.704)	-5.149 (5.969)
August	-0.671 (1.320)	-6.423 (10.28)	-3.324 (2.999)	-7.845 (9.465)
September	-0.501 (1.260)	-6.297 (12.87)	-2.317 (2.653)	-7.790 (11.99)
October	0.259 (0.772)	-2.129 (5.195)	1.018 (1.385)	-2.790 (5.135)
November	-0.213 (0.874)	-4.291 (14.39)	1.045 (1.935)	-5.543 (14.02)
December	-1.729 (7.911)	-3.219 (12.01)	-3.513 (6.999)	-4.356 (12.72)
1994	-4.662 (23.96)	-2.567 (10.14)	-9.262 (22.58)	-4.249 (12.72)
1995	-5.927 (31.36)	-2.453 (10.11)	-12.292 (30.29)	-4.283 (13.37)
1996	-6.464 (37.24)	-1.881 (8.365)	-13.311 (36.34)	-3.718 (12.54)

continues on the next page

Table 5.6: *OLS and Tobit estimation results continued*

	OLS		Tobit	
Variable	GFT	RST	GFT	RST
WON A	-1.169 (9.038)	1.781 (11.26)	-5.228 (18.43)	1.977 (9.468)
WON B	2.307 (7.966)	2.453 (6.925)	4.479 (7.433)	3.366 (7.193)
WON C	-3.971 (15.66)	2.324 (6.865)	-5.007 (9.234)	3.056 (6.847)
WON D	-7.509 (27.38)	-0.624 (1.177)	-2.611 (4.801)	-2.800 (3.962)
WON E	-5.411 (9.696)	6.846 (10.03)	-22.480 (14.81)	6.243 (6.840)
WON F	-2.222 (18.26)	1.592 (10.70)	-10.133 (36.40)	1.673 (8.505)
WON G	-5.654 (15.18)	5.306 (11.65)	-18.957 (20.42)	5.274 (8.802)
WON H	-4.505 (4.090)	13.750 (10.20)	-12.181 (4.602)	16.824 (9.623)
WON I	-6.171 (2.571)	-3.502 (1.193)	-135.26 (0.168)	-3.348 (0.826)
Joint container	–	-7.862 (8.576)	–	-7.286 (6.026)
Adjusted-R^2	0.115	0.126		
F_{k-1,N_T-k}	-12.7	-13.4		
Loglikelihood			-305,535	-459,109
Resticted loglikelihood			-538,622	-565,104
LR test χ^2_{k-1}			466,173	211,989
N_T	127,581	127,581	127,581	127,581

Ordinary Least Squares

Our focus on the fixed effects specifications is not completely without loss of information. We cannot include exogenous variables which show no variation for a household, such as the type of dwelling. In particular, the presence of a garden is likely to be an important determinant of compostable waste production. Moreover, the type of dwelling is also related to income: higher income households will usually live in larger dwellings. Using OLS and Tobit estimation we estimated the demand for household waste collection without individual effects. Note that the disadvantage of these methods is that the observations in the survey should be uncorrelated which is definitely not the case in the Oostzaan survey. Below we briefly discuss the results of the OLS and the Tobit estimation.

The first and second column of table 5.6 show the OLS estimation results. For compostable waste and non-recyclable waste the of the marginal price coefficient is negative: -0.320 and -0.282 respectively. In the latter case, the coefficient only applies to households with a personal GFT container. The marginal price coefficient of non-recyclable waste for households with a joint GFT container is -0.148. Households with a joint GFT container are less sensitive to price changes in the collection of non-recyclable waste than households with a personal container. Moreover, on average households with a joint GFT container present 7.9 kilogram less non-recyclable waste than households with a personal GFT container.[23]

An important determinant of compostable waste is the presence of a garden. Since we do not observe the presence of a garden, we include the type of dwelling. Only dwellings for the elderly show a significant positive effect as compared to non-detached dwellings. In all other types of dwellings less compostable waste is generated. Remarkably, households living in detached and semi-detached dwellings generate less compostable waste than the non-detached dwellings, despite the fact that detached and semi-detached dwellings presumably have larger gardens. However, larger gardens imply two opposite effects. On the one hand households produce more yard waste due to the larger garden, and on the other hand more garden surface implies that it is more easy to place home composting containers. Hence the results indicate that the latter effect dominates over the first effect.[24] In contrast with compostable waste, households living in most other types of dwellings as compared to households living in non-detached dwellings produce more waste. The exceptions are households living in an apartment building on one of the higher floors and households living in a summerhouse.

Tobit estimation

The third and fourth column of table 5.6 show the estimation results of the Tobit type of specification for compostable and non-recyclable waste. The price coefficient are negative and significant, -0.577 and -0.319 for compostable and non-recyclable waste respectively. For households with a joint GFT container the marginal price coefficient for non-recyclable waste collection is -0.195. Note that these households present 7.3 kilogram less non-recyclable waste than households with a personal GFT container. Although the magnitude of the coefficients differ, the signs of these results are similar to the OLS results.

[23] The difference in the non-recyclable price coefficients cannot be explained by dwelling type, age or household size, since these determinants are included in the regression equation.

[24] In Oostzaan the purchase of a compost container has been stimulated by the municipality with a subsidy on the purchase price of a home compost container.

Table 5.7: *Elasticities of marginal prices on the demand for household waste collection*

Model specification	GFT waste	RST waste
SHORT RUN		
Fixed Effects	-1.194	-0.478
Fixed Effects including lag	-1.100	-0.264
OLS	-1.100	-0.515
Tobit	-0.484	-0.532
LONG RUN		
Fixed Effects including lag	-1.392	-0.340

[a]The elasticities are calculated in the sample means.

The trend in the Tobit results with respect to the type of dwelling is similar to the OLS results. There is only one exception. Households living in an apartment produce significantly less non-recyclable waste. As with other Tobit results, the difference with the OLS results is that in most cases the absolute values of the Tobit coefficients are much higher.

Elasticities

Based on the estimation results shown above we calculated elasticities for the marginal prices. Table 5.7 shows the elasticities which are calculated in the sample means. We distinguish elasticities for compostable and non-recyclable waste as well as long-run and short-run price elasticities.

Table 5.7 shows the price elasticities of the demand for household waste collection. The elasticities are calculated for both compostable and non-recyclable waste. The results show that the elasticities are higher than earlier findings in the literature (see table 5.2). Except for the Tobit specification, the price elasticities of compostable waste are higher than the non-recyclable waste elasticities. The reason is that in the case of compostable waste there is an alternative of home composting. Such an alternative is not present in the case of non-recyclable waste.

For GFT waste the long-run price elasticity is larger than all the short-run price elasticities of estimate specifications. In the case of RST waste the long-run price elasticity is larger than the short-run price elasticity in the same specification. However, both elasticities are smaller than the elasticities found with the other specifications.

Table 5.8: *Income elasticities of the demand for household waste collection in the Netherlands*

Variables	Annual household waste
Intercept	-1,204.32 (1.227)
Trend	11.062 (1.740)
Average family size	244,38 (1.508)
Average household income	0.007 (7.999)
N	34
R^2	0.87

With the Oostzaan sample we estimated the four specifications. As mentioned in the previous subsection we are not able to determine the income effect. Using a macro time series of annual data[25] on household waste in kilograms and disposable income per capita in the Netherlands in the period $1960-1994$, however, we estimated an income elasticity of 0.60.[26] Table 5.8 shows the estimation results.

Except the intercept, all coefficients are significant at a ten percent level. According to our findings there is an 11 kilogram autonomous annual growth in the average annual household waste. Furthermore, with the addition of one person to the household, the average annual household waste increases with 244 kilograms.

5.5 Discussion

The results of the previous section showed that the implementation of weight-based pricing in Oostzaan had a strong effect on the amount of waste presented for collection. In addition to the desired behavioral changes (such as home composting, using less packages when shopping, hauling glass, paper, etc. to special containers), the program may have triggered adverse behavioral effects. In Oostzaan these effects have been thoroughly investigated.[27] About 4 to 5 percent of the waste is brought to neighboring municipalities or to employers (for comparison: in the first year after the introduction of weight-based pricing the

[25] Note that the aggregated data include both compostable and non-rcyclable waste.

[26] We used a linear specification. The income elasticity was calculated in the sample mean; the average annual household income was 76,042 guilders and the average annual waste weight was 894 kilograms. With a double logarithmic specification we found similar results for the income elasticity.

[27] The results have been described in PME Adviesbureau BV, *Afval voorkomen werkt* (Preventing waste pays), Zeist, 1994.

mount of waste collected by the municipality decreased by about 30 percent). The municipality provides households opportunities to report any misconduct of waste littering or illegal dumping. All the reported misconducts are checked by controllers of the municipality. In many cases the responsible household is traced by investigating the contents of the waste bag littered. The household then has to pay for the waste collection and is fined as well. This system of monitoring and fining illegal dumping appears to be very effective in terms of deterrence: Illegal dumping is virtually non-existent. Sewage samples did not show any evidence of illegal waste dumping.

Table 5.9: *Shares of waste components (in percentages) in the total annual amount of waste during the period* $1992 - 1996$

Type of waste	1992-93	1993-94	1994-95	1995-96
non-recyclable waste	39.3	28.7	30.0	29.5
compostable waste	26.7	20.8	15.3	15.0
recyclable paper	22.0	30.1	33.7	34.6
recyclable glass	5.9	11.4	13.9	12.7
recyclable textiles	1.1	1.7	1.9	2.1
recyclable tins	0.2	2.1	2.1	1.9
small chemical waste	0.2	0.2	0.3	0.2
large volume units	3.6	3.9	2.2	3.2
refrigerators	0.2	0.2	0.2	0.2

The columns apply to the period July, 1 up to June, 30 of the next year.

Whether a system of weight-based pricing can be implemented successfully crucially depends on the type of municipality and its social structure. Oostzaan is a relatively small countryside village with a certain degree of social control. In larger communities with predominantly apartment buildings the conditions for successful implementation are less favorable.

For the municipality of Oostzaan, the net costs of waste collection and processing did not increase as a result of the new system. The increased costs of collection, control and administration were compensated by the reduction in processing costs resulting from a lower total amount of waste. For households, the average charge for waste collection increased slightly during the sample period but to a much smaller extent than in neighboring municipalities that use the traditional fixed fees system.

Fullerton and Kinnaman (1996) found that the recyclable materials increased with 15 percent due to the introduction of a price per container. Although information on the amounts of recyclable waste is not available on a household level, we do have the aggregate amounts of the municipality of Oostzaan; table 5.9. There was a large increase for glass (36 percent) and tins (60 percent). Recall that the separate curbside collection program for paper already existed before the introduction of weight-based pricing. Also note that the collection of large volume units and refrigerators is not free of charge.

5.6 Conclusions

In Oostzaan weight-based pricing has a strong effect on the amount of waste presented for collection even in the long run. For compostable we found price elasticities of -1.2 and -1.4 for the short run and long run respectively. In the case of non-recyclable waste we found short-run price elasticities within the range of -0.5 to -0.26, and long-run price elasticities of -0.34. The estimates are much larger than those found in earlier studies on volume-based pricing. The substantial annual reduction and the high elasticities of the GFT waste presented for collection indicate that households use alternatives such as home composting more often. The amounts of recyclable materials that can be dropped off free of charge increased substantially. In Oostzaan weight-based pricing appears to be cost effective. The problem of illegal dumping is small, due to an effective monitoring and fining system.

Practical problems limit the implementation of weight-based pricing to communities with a certain degree of social control and relatively small number of apartment buildings. However, there are many such municipalities in the Netherlands and elsewhere.