Chapter 8
Dutch Cost Savings in Unit-Based Pricing of Household Waste

E. Dijkgraaf and R.H.J.M. Gradus

Abstract We estimate the effects of four unit-based pricing systems on waste collected in Dutch municipalities. Unit-based pricing is shown to be effective in reducing unsorted and compostable waste and in stimulating recyclable waste. If the estimations are corrected for differences in environmental activism between municipalities the effects are still large but significantly lower. The bag-based and weight-based systems perform equally and far better compared with the frequency-based and volume-based systems. This is interesting, as administrative costs are significantly lower for the bag-based system. Finally, unit-based pricing has no effect on the amounts of waste collected in surrounding municipalities.

Keywords Municipal waste management · unit-based pricing systems · environmental activism

8.1 Introduction

More and more Dutch communities have implemented unit-based user fees to finance waste collection. These user fees require households to pay for each kilogram, bag or can presented at the curb for collection. By 2000, more than 20% of all Dutch municipalities had implemented such a system. In this chapter, we estimate household reactions to the implementation of unit-based pricing for the collection of residential waste. Our estimates show significant and sizable price effects, which depend on the type of unit-based pricing.

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Table 8.1 Overview of the econometric literature on effects of unit-based pricing

Study	Country	System	Elasticities		
			Price[a]	Own-price[b]	Cross-price[c]
Household surveys					
Hong et al., 1993	USA	Volume	3.63	not sig.	> 0
Van Houtven & Morris, 1999	USA	Volume	0.22	–0.10	not sig.
Jenkins, Martinez, Palmer, & Podolsky, 2003	USA	Volume[d]	2.13		not sig.
Reschovsky & Stone, 1994	USA	Bag (recyclable)	0.85		not sig.
Reschovsky & Stone, 1994	USA	Bag (compost)	0.85		> 0
Fullerton & Kinnaman, 1996	USA	Bag	0.89	–0.08	0.07
Van Houtven & Morris, 1999	USA	Bag	0.86	–0.26	not sig.
Hong, 1999	Korea	Bag	1.49	–0.15	0.46
Linderhof et al., 2001	NL	Weight (compost)[e]	3.86	–1.39	
Linderhof et al., 2001	NL	Weight (unsorted)[e]	4.14	–0.34	
Aggregate municipality data					
Wertz, 1976	USA	Volume	5.85	–0.15	
Jenkins 1993	USA	Volume	1.46	–0.12	
Strathman et al., 1995	USA	Volume	5.69	–0.45	
Van Houtven & Morris, 1999[f]	USA	Volume	0.22	< 0	
Kinnaman & Fullerton, 1997	USA	Bag	0.16	–0.19	0.23
Podolsky & Spiegel, 1998	USA	Bag	3.62	–0.39	
Van Houtven & Morris, 1999[f]	USA	Bag	0.86	–0.15	
Kinnaman & Fullerton, 2000	USA	Bag	0.09	< 0	not sig.
Callan & Thomas, 1997	USA	Mixed[g]	n.a.		0.07

[a]Average tariff in real US dollars (2000) per 30 gallons (114 liters) of unsorted waste.
[b]Elasticity of the amount of collected unsorted waste with respect to the price of unsorted waste collected at the curbside.
[c]Elasticity of the amount of collected recyclable (and/or compostable) waste with respect to the price of unsorted waste collected at the curbside.
[d]Of the 1,049 households, 116 face a positive unit price, of which 104 subscribe to collection of a pre-specified number of cans and 12 pay per bag/tag/sticker.
[e]In Oostzaan, the city Linderhof et al. (2001) study, both compostable and unsorted waste are priced on a weight basis.
[f]Data are aggregated per sanitation route.
[g]In Massachusetts, different unit-based pricing systems exist (bag, tag, volume). This study does not discriminate between the different programs.

Two streams of literature that estimate household reactions to the implementation of unit-based pricing systems can be distinguished. The first uses cross-sectional analyses of municipalities and the second applies household survey data. Most of the studies show considerable impacts from a pricing system. Table 8.1 summarizes the existing econometric literature with respect to the effects of unit-based pricing. In general, nearly all studies find a negative and significant own-price effect from unit-based pricing. The results are more mixed for the cross-price effect on collected recyclable waste.

Most studies evaluate bag- or volume-based systems. Only Linderhof Kooreman, Allers and Wiersma (2001) study the effects of the most refined, weight-based system. Table 8.1 indicates that own-price elasticities overlap for the different unit-based pricing systems. For example, Strathman, Rufolo, and Mildner (1995) found an elasticity of –0.45 for the volume-based system, which is higher than the elasticities of the bag-based systems, while Hong, Adams, and Love (1993) found a non-significant elasticity. Direct comparison of systems is limited to Van Houtven & Morris (1999). This chapter compares the effects of bag- and volume-based systems and finds a significantly higher elasticity for the bag-based system for curbside-collected unsorted waste. The effect on the quantity of waste recycled is found to be insignificant in both cases.

We extend the literature in three directions. Firstly, we explicitly distinguish between the different systems of unit-based pricing (weight-based, bag-based, frequency-based and volume-based pricing). This contributes to the literature because no study presents a direct comparison of the possible unit-based pricing systems. Our results clearly indicate that the bag- and weight-based systems perform far better than the other systems. Secondly, we investigate whether environmental activism is responsible for part of the estimated price effect. Our research shows that municipalities that introduce a unit-based pricing system already produce less waste on average before its introduction. When no correction is made for this effect, price effects estimated on the basis of cross-section data might overestimate the true effects. Thirdly, we test whether surrounding municipalities without unit-based pricing systems in fact collect part of the waste produced in municipalities with unit-based pricing systems. No such effect seems to be present in Dutch municipalities.

8.2 Effects of Unit-Based Pricing

8.2.1 Method and Data

In previous studies using cross-sections of municipalities, waste per capita is a function of price, the municipality's mean level of income, the share of homeowners, the age distribution, the average number of people in a household and other demographic variables (see for example Fullerton & Kinnaman, 1996). We use the quantity of waste collected (in kilograms per inhabitant) also as the dependent variable. However, we are able to discriminate between different waste streams. In the Netherlands, municipalities are obliged to collect three types of waste separately: compostable waste such as vegetable, food and garden waste; recyclable waste such as glass, paper and textiles; and unsorted waste. Furthermore, municipalities are obliged to collect compostable and unsorted waste at the curbside. For recyclable waste, municipalities can choose whether they collect at the curbside or provide drop-off centers.[1] For municipalities without curbside collection of recyclable waste, the number and location of drop-off centers must be such that the collection infrastructure is easily accessible for all citizens. For example, municipalities place collection units at shopping centers and at entrance roads of neighborhoods.

Data on the dependent variables, the quantities collected of total, unsorted, recyclable and compostable waste in kilograms per inhabitant, come from studies by the Dutch Waste Management Council (AOO). Total waste collected is calculated as the sum of unsorted, recyclable and compostable waste. The AOO-studies present data on the quantities of paper, glass, textiles, compostable and unsorted waste collected for 1998, 1999 and 2000. The AOO uses an annual inquiry from the CBS (the Dutch Central Bureau for Statistics), which is sent to the waste collection units of all Dutch municipalities. These units have reliable figures for the quantity of waste collected as the bill they have to pay is based on the quantity of waste supplied to waste treatment firms. These firms weigh the waste each time a collection vehicle brings waste to the treatment plant. The CBS checks the quality of the data by comparison with other years and by comparison with additional information from waste treatment companies.[2] Additionally, as the data for sorted waste are partly collected by schools and charitable organizations, information from regional and national representative organizations for glass, paper and textiles recycling is used to check these data. The response rate of the inquiry is 91%. Thus, our data-set comprises nearly all Dutch municipalities. The actual number of municipalities included differs for each dependent variable due to data availability. The first four rows in Table 8.2 present summary and availability statistics for the dependent variables (see the Appendix for the variable definitions).[3]

Dutch municipalities are free to choose the financing mechanism for waste collection. Most municipalities finance waste collection by a flat rate (see Table 8.3). This results in a marginal price of zero. In order to promote waste prevention and recycling, a number of municipalities have introduced a unit-based pricing system. In general, the Dutch unit-based pricing systems generate marginal prices for unsorted and compostable waste, while the collection of recyclable waste (glass, paper and textiles) is still free. This gives citizens the incentive to sort their waste and to change their buying behavior. Different Dutch municipalities have introduced different types of unit-based pricing systems. These systems can be ordered with respect to the refinement of the pricing system. It could be expected on theoretical grounds that as marginal pricing becomes more and more refined, households respond with greater reductions in priced waste streams and a growing supply of unpriced waste streams.

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[1] In some municipalities, there is a free curbside collection program for recyclable paper organized by local associations, such as sports clubs and schools. Our data include the waste collected by these associations.

[2] In the inquiry, municipalities are asked which companies treat the waste. Information from these companies is gathered to make comparison possible.

[3] As not for all municipalities data are available for all years, the number of observations is not exactly equal to the number of years multiplied by the number of cross-sections.

Table 8.2 Descriptive statistics

	Mean	Maximum	Minimum	Standard deviation	Number of observations	Number of cross-sections
$Waste_{total}$	431	707	222	62	1.323	507
$Waste_{unsorted}$	218	450	52	54	1.451	530
$Waste_{compost}$	117	239	12	39	1.449	529
$Waste_{recyclable}$	99	217	19	20	1.334	508
UBP_{weight}	0.02	1.00	0.00	0.14	1.451	530
$UBP_{bagunscom}$	0.01	1.00	0.00	0.11	1.451	530
UBP_{baguns}	0.02	1.00	0.00	0.15	1.451	530
UBP_{fre}	0.07	1.00	0.00	0.26	1.451	530
UBP_{vol}	0.05	1.00	0.00	0.22	1.451	530
UBP_{oth}	0.01	1.00	0.00	0.12	1.451	530
Retire	13.31	27.77	6.38	2.90	1.451	530
Fam size	2.56	3.70	1.72	0.20	1.451	530
Foreigner	0.04	0.31	0.00	0.04	1.451	530
City	0.05	1.00	0.00	0.22	1.451	530
Village	0.57	1.00	0.00	0.50	1.451	530
Density	0.50	27.46	0.02	1.35	1.451	530
Ownhouse	10.05	30.59	1.34	3.12	1.451	530
Ownflat	1.68	16.53	0.00	2.20	1.451	530
Income	39.04	44.60	28.50	2.34	1.451	530

Table 8.3 Occurrence of unit-based pricing systems

	1998	1999	2000
Municipalities with unit-based pricing systems			
Weight-based system	9	10	13
Bag-based system for both unsorted and compostable waste	6	6	6
Bag-based system for unsorted waste	13	12	14
Frequency-based system	19	43	54
Volume-based system	24	30	29
Unspecified type of system	6	8	10
Total	77	109	126
Municipalities without unit-based pricing systems	461	429	412
Total	538	538	538

In general, four different systems are present: volume-based, frequency-based, bag-based and weight-based.[4] Table 8.3 gives an overview of the pricing systems used by Dutch municipalities in the period 1998–2000 based on the annual AOO inquiry.

The volume-based program allows households to choose between different volumes of collection can. Most municipalities supply a standard can with a volume of

[4] Some municipalities have a combination of the different unit-based pricing systems or apply the pricing system to only part of their municipality. These are included in Table 8.3 as ‘unspecified type of system’.

140 liters (37 gallons), with the possibility of upgrading to a 240-liter (63 gallon) can or of subscribing to more 140-liter cans. In general, citizens can choose different volumes for unsorted and compostable waste. The marginal price in the volume-based system is rather crude, as the decision on the optimal level of waste supply can only be made at the beginning of the contract period and at certain review times (usually annual). In 2000, 29 municipalities in the Netherlands used a volume-based pricing system.

A more refined marginal price results from a frequency-based system, in which the household pays for the number of times the can is presented at the curbside. The payment is not dependent on the actual amount of waste the can contains. Whether the can is filled or half empty, the bill household receive is just equal to the number of times the can is presented. The occurrence of frequency-based pricing systems shows a notable rise between 1998 and 2000. In 2000, this type of system was the most frequently used pricing system.

In the bag-based system, households have to buy a special bag with specific marks. In most cases, these bags can be bought at supermarkets, petrol stations and the town hall. Other bags without the relevant marks are not collected. The bag-based system is a more refined pricing system than the frequency-based system, as the volume of the bag is significantly less than that of the can. In the Netherlands, the volume of bags is 50 or 60 liters (13 or 16 gallon). An important difference compared with other unit-based pricing systems is that the most frequently used bag-based system leaves compostable waste unpriced. In 2000, 14 municipalities used a bag-based system for unsorted waste in combination with a free collection can for compostable waste. Only a minority of municipalities that have a bag-based system use bags for both unsorted and compostable waste (6 municipalities in 2000). As the incentives of the two systems differ, we include both types separately in the estimations.

Maximum flexibility results from a weight-based system. The collection vehicle weighs the can and combines this information with the identity of the owner, stored in a chip integrated in the collection can. In this case, a greater weight of waste results in a higher collection fee. While the number of municipalities using a weight-based system has increased, in 2000 still only 13 municipalities had introduced such a system.

As data are available for 1998–2000, we estimate a panel model using both the cross-section and the time-related variation.[5] For each waste stream (total waste, unsorted waste, recyclable waste and compostable waste), we estimate:

$$Waste_{w,i,t} = \alpha_s UBP_s + \beta SE + c_i + d_t + \varepsilon_{i,t}, \tag{8.1}$$

[5] We tested the assumption that pooling the different years is valid. An F-test on the sum of squared residuals rejected this assumption at the 99% level (F-statistic is 2.04). However, we only present results for the pooled model because a comparison with results for the separate years showed that the estimated coefficients are very robust. Only for the frequency variable was the coefficient significantly different from the panel estimates at the 95% level for 1998 (–0.11) and 2000 (–0.29). The reason for this is the sharp rise in the number of municipalities using the frequency system.

where $Waste_{w,i,t}$ is the quantity of waste stream w in municipality i in year t, UBP_s are dummies with the value 1 if municipality i has a unit-based pricing system of type s in year t, SE is a vector of socio-economic characteristics, c_i are time-invariant regional fixed effects,[6] d_t are time fixed effects and $\varepsilon_{i,t}$ is the normally distributed error term (where necessary corrected for cross-sectional heteroskedasticity).[7]

To correct for differences between municipalities, we include the following socio-economic characteristics: the area of a municipality per inhabitant (and its square), the average family size, the number of non-western foreigners per inhabitant, the percentage of total inhabitants earning a median income, the number of houses sold per inhabitant, the number of flats sold per inhabitant, a dummy for small municipalities, a dummy for large municipalities and the percentage of inhabitants older than 65.[8] Data for the socio-economic characteristics come from the CBS (the Dutch Central Bureau for Statistics). Descriptive statistics for the variables are given in Table 8.2.

8.2.2 Results

Table 8.4 presents the estimation results. The F-statistics show that the equations are significant, while the relatively high (adjusted) R^2s indicate that the explained variation is not small.

Pricing waste on the basis of weight has a highly negative and significant effect on total waste of 38%.[9] This effect differs for the underlying waste streams. Compostable waste diminishes by more than 60%. It seems that many Dutch households use home composting methods to reduce this type of waste. Also, the effect on unsorted waste, the most environmentally unfriendly waste stream, is large: introducing a weighing system reduces the amount by nearly 50%. From the estimations, it is

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[6] Ideally, we would include a fixed effect for each municipality. However, as the unit-based pricing system dummies are highly invariant with respect to time, this is not possible. As a second best, we include a dummy for each province. Results for these fixed effects are available upon request.

[7] We tested all specifications for heteroskedasticity using the Breusch-Pagan test. It showed that for estimations with the independent variables in levels, heteroskedasticity could not be rejected. Therefore we estimated with the independent and, where possible, right-hand-side variables in logs (see Appendix). In cases where heteroskedasticity could still not be rejected, we corrected the standard errors with the White procedure (see Table 8.4).

[8] We tested the robustness of the estimated coefficients for the unit-based pricing systems by estimating a wide variety of different equations. Excluding some of the control variables or including extra control variables (such as the percentage of inhabitants in full-time work, the percentage of western foreigners, the number of families with 1, 2 or more children, the amount of property tax paid and the size of the agriculture sector) showed that the estimated coefficients for the unit-based pricing systems are very robust. For example, the coefficients for total waste are between –0.48 and –0.53 for the weight-based system and between –0.23 and –0.26 for the frequency-based systems. Further results are available upon request.

[9] As the dependent variable is in logs, the effects of the pricing dummies are calculated using e^x-1, where x is the estimated coefficient.

Table 8.4 Estimation results: dependent is ln(*Waste*)

	Total	Unsorted	Compostable	Recyclable
UBP_{weight}	–0.48	–0.68	–0.95	0.19
	(0.02)	(0.03)	(0.05)	(0.03)
$UBP_{bagunscom}$	–0.44	–0.68	–0.93	0.26
	(0.02)	(0.04)	(0.06)	(0.03)
UBP_{baguns}	–0.15	–0.74	0.31	0.15
	(0.02)	(0.03)	(0.04)	(0.02)
UBP_{fre}	–0.24	–0.32	–0.46	0.09
	(0.01)	(0.02)	(0.03)	(0.02)
UBP_{vol}	–0.07	–0.13	–0.01#	0.03#
	(0.02)	(0.02)	(0.03)	(0.02)
UBP_{oth}	–0.15	–0.47	–0.02#	–0.01#
	(0.03)	(0.04)	(0.06)	(0.05)
ln(Retire)	0.11	0.04#	0.27	0.09**
	(0.02)	(0.03)	(0.05)	(0.04)
ln(Fam size)	–0.24**	–0.61	0.55	0.31*
	(0.08)	(0.11)	(0.17)	(0.16)
ln(Foreigner)	–0.03	–0.00#	–0.12	–0.02*
	(0.01)	(0.01)	(0.02)	(0.01)
City	–0.05	0.01#	–0.23	–0.15
	(0.01)	(0.02)	(0.04)	(0.03)
Village	0.01#	–0.03**	0.03*	0.05
	(0.01)	(0.01)	(0.02)	(0.02)
ln(Density)	0.03	0.09	0.03*	0.00#
	(0.01)	(0.01)	(0.01)	(0.03)
$(\ln(Density))^2$	0.004*	0.028	–0.016	0.002#
	(0.002)	(0.003)	(0.005)	(0.009)
Own_{house}	0.002**	0.003*	0.015	0.002#
	(0.001)	(0.002)	(0.003)	(0.002)
Own_{flat}	–0.007	0.001#	–0.024	–0.013
	(0.002)	(0.003)	(0.004)	(0.004)
ln(Income)	0.24	0.24	0.07#	0.27#
	(0.06)	(0.09)	(0.14)	(0.17)
R^2 (adjusted)	0.63	0.68	0.63	0.26
F-statistic	77.31	106.85	87.80	17.50
White correction	Yes	No	No	Yes
Fixed effects	Yes	Yes	Yes	Yes
Number of observations	1,323	1,451	1,449	1,334

Notes: Equations are estimated including a constant. Standard errors are given in parentheses. All coefficients are significant at the 99% confidence level, except for coefficients with **(*) which denotes significance at the 95% (90%) level and for coefficients with # which denotes non-significance at the usual levels.

clear that one of the important mechanisms generating this result is that the amount of recyclable waste increases when a unit-based pricing system is introduced: introducing the weight-based system leads to higher efforts in recycling glass, paper and textiles (up 21%). Of course, this is due to the fact that Dutch citizens do not have to pay a marginal price for the collection of this type of waste. Given the cross-price effect, the net decrease in unsorted waste is 29%.

Introducing a bag-based pricing system also reduces the amount of total waste. In municipalities that use the bag-based system both for unsorted and for compostable waste, total waste diminishes by 36%. For municipalities that collect compostable waste by using a free collection can, the reduction is only 14%. While the effects on unsorted waste are comparable for the two systems (–49% and –52%), the effects on the supply of compostable waste differ greatly. In municipalities with unpriced compostable waste collection, compostable waste increases (by 36%), while in the other municipalities (using a bag system for compostable waste as well as for unsorted waste), this waste decreases (by 61%). Interestingly, the effect on recyclable waste is also larger for municipalities that use the bag-based system for compostable waste. This suggests that in municipalities using a bag-based system only for unsorted waste, part of the recyclable waste is 'dumped' in the free compostable waste can. The intuition behind this result is that it takes less effort to use this can than to use the recyclables facility. The compostable waste can is in the direct vicinity of the house, while the collection infrastructure for recyclable waste is farther away, resulting in more time needed to deliver the recyclables. Interestingly, the effects of the bag-based system that prices both unsorted and compostable waste are comparable to those of the weight-based system.

The system based on frequency reduces the total amount of waste by 21%, due to a reduction in both unsorted waste (27%) and compostable waste (37%). As the effects on unsorted waste are less pronounced than in the weight-based and bag-based systems, the stimulating effect on the collection of recyclable waste is smaller as well (up 10%).

The effects of introducing a system based only on the volume of the collection are smaller. Total waste decreases by only 6%, mainly due to the effect on unsorted waste as the effects on compostable and recyclable waste are insignificant. This result is not surprising since the volume-based system is less refined than the other systems.

Turning to the socio-economic characteristics, we find economies of scale for total waste. This corresponds to the results found in the literature. An increase in household size of one standard deviation reduces collected waste per inhabitant by 5%. Diseconomies of scale are found for compostable waste. A possible explanation is that households with three or more people are more likely to have a garden.

In addition, the amount of waste per capita is larger for municipalities with a larger population of elderly people or a smaller population of foreign people. This is especially the case for compostable waste. As the garden area of the household primarily determines the amount of compostable waste, it is clear that living in a city has a highly significant and negative effect on compostable waste and living in a village has a positive effect. Furthermore, as we should expect, the sign on compostable waste is negative for municipalities with many flats. Moreover, a larger area per inhabitant increases the waste stream. The coefficients on income for total and unsorted waste are in accordance with the literature and positive, while income has no influence on compostable and recyclable waste.

8.2.3 The Price Elasticities of the Pricing Systems

So far, we have estimated the effects of unit-based pricing systems using dummies for the different systems, as no information is available on tariffs for 1998–2000. However, we do have data on the tariffs in 2003.[10] Assuming that these tariffs are a proxy for the real tariffs in 1998–2000, we can estimate the price elasticities of the different unit-based pricing systems. This makes comparison with results found in the literature easier.

Table 8.5 presents the estimated elasticities. Consistent with the results presented in Table 8.4, the price elasticities are highest for the weight-based system and the bag-based system that prices both unsorted and compostable waste. This is interesting, as the average tariff for the weight-based system is more than twice that for the bag-based system. The better results for the bag-based system are very clear when the elasticities of the volume and frequency systems are compared. While the average tariff for the volume-based system is more or less equal to that of the bag-based system and the tariff for the frequency system is 1.89 dollars higher, their elasticities are significantly lower.

The higher price elasticity for unsorted waste in the bag-based system than in the volume-based system is in line with the results of Van Houtven & Morris (1999). The much smaller average tariff for the bag based system in their study than in ours might explain the lower own-price elasticity found for the bag-based system and the insignificant effects on recycling compared with our findings.

Table 8.5 Estimated price elasticities

System	Price	Total	Unsorted	Compost	Recyclable
Standard model					
Weight	4.39	–0.47	–0.67	–0.92	0.16
Bag, unsorted + compostable	2.02	–0.43	–0.66	–0.97	0.25
Bag, unsorted	2.15	–0.14	–0.71	0.29	0.14
Frequency	3.91	–0.22	–0.28	–0.40	0.08
Volume	1.94	–0.06	–0.12	–0.01#	0.01#
Model with environmental activism					
Weight	4.39	–0.40	–0.53	–0.81	0.12
Bag, unsorted + compostable	2.02	–0.36	–0.51	–0.85	0.20
Bag, unsorted	2.15	–0.07	–0.58	0.40	0.09
Frequency	3.91	–0.16	–0.16	–0.31	0.04*
Volume	1.94	–0.00#	0.01#	0.09	–0.03#

Note: Equations are estimated including the same socio-economic characteristics as presented in Table 8.4 (results are highly comparable and available on request).

[10] In the estimations we use the tariffs charged each time a can is emptied for the frequency system. For the volume system, we use the marginal weekly increase in the collection fee if a household subscribes to a larger can. To make comparisons between systems possible, the reported tariffs in Tables 8.1 and 8.5 are in real (2000) US dollars (using the GDP deflator) per 30 gallons (114 liters) of unsorted waste. Tariffs per mass unit are transformed to tariffs per volume unit using a regularly reported maximum weight of 0.76 kilograms per gallon (3.79 liters).

Compared with the elasticities found in the literature, our estimated own-price elasticities for the bag-based and weight-based systems are high. For example, the study with the highest elasticity for the bag-based system (Podolsky & Spiegel, 1998) finds an elasticity of only −0.39.

Comparing the average tariffs charged in Dutch municipalities with the average prices charged by communities whose elasticities are estimated in the literature reveals that the average Dutch tariff for the volume-based system is similar to the average tariffs reported in other studies (compare Tables 8.1 and 8.5). The average Dutch tariffs for the frequency-based, bag-based and weight-based systems are inside the range of tariffs evaluated in the literature. Thus, the higher own-price effects we estimated are not the result of higher prices in the Netherlands.

Interestingly, the cross-price elasticities we found for recyclable waste are not outside the range found in the literature. This suggests that the larger effects of bag-based and weight-based pricing in the Netherlands are not the result of more substitution between unsorted and recyclable waste. In the next two sections, we analyze whether the high Dutch elasticities are influenced by citizens' environmental activism and by leakage effects to neighboring municipalities.

8.3 The Importance of Environmental Activism

Section 8.2 shows that unit-based pricing systems have a significant effect on the quantity of collected waste. Part of this effect may, however, result from a higher level of environmental activism. Figure 8.1 illustrates this point. Assume that citizens in municipality B (where unit-based pricing is introduced in the second period) are more concerned about the waste problem than citizens in the flat-fee municipality, A. Our method to estimate the effects of unit-based pricing systems compares the waste quantities of both municipalities, resulting in an estimate that is the sum of the environmental-activism effect and the price-system effect. The true effect of the price system for municipalities with a level of environmental activism comparable to that in municipality B is, however, equal to the difference in the second period

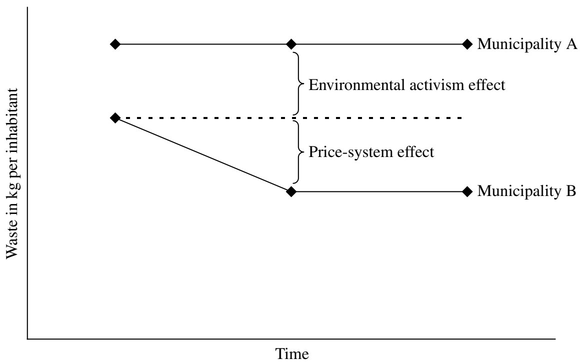

Fig. 8.1 Influence of environmental activism on quantity of waste

minus the difference in the first period. The figures presented in Table 8.4 thus can overestimate the effects of unit-based pricing on the waste quantity of municipalities where such a system is introduced.

A way to deal with the environmental-activism effect is to take into account the political affiliation of the population. For example, Linderhof et al. (2001) suggest that because of the political affiliation of Oostzaan the estimated effects of the weight-based system of Oostzaan may not generalize for other municipalities. They evaluate the introduction of weight-based pricing in this small Dutch city using data before and after introduction of the pricing system. The largest political party in Oostzaan is Green Left (38% of the total vote), which is the most environmentally-friendly-oriented political party in the Netherlands. Green Left received only 7% of the votes nationwide in the parliamentary elections of 1998. This suggests that environmental activism is relatively high in Oostzaan, resulting in less-than-average amounts of waste before the introduction of the weight-based pricing system. Thus, the effect of introducing such a system in municipalities with less environmentally conscious citizens might be larger.

To check the influence of environmental activism, we included the fractions of the vote attained by each political party (based on the local election results of March 1998) in the estimations presented in Table 8.4. The Dutch political parties have different preferences with respect to environmental issues. There is consensus in the Netherlands about the position of most parties on an environmental left-right scale. For example, based on an evaluation of election programs, the Dutch Friends of the Earth gave Green Left an 8 for environmentally friendly policy proposals, while the right liberal party (VVD) was only given a 4.[11] It could be expected that municipalities in which green parties received a high percentage of the votes produce less waste than right-wing municipalities. However, statistical analysis shows that none of the Dutch political parties has a significant influence on the total amount of waste and therefore we conclude that political affiliation is a weak explanatory variable for environmental activism.[12]

Therefore, we check the influence of environmental activism in another way.[13] The communities that most want to recycle and to minimize waste going to disposal might be the ones that choose unit-pricing systems. If so, the pricing system and environmental activism are simultaneously determined with waste quantity. Therefore, the estimated effects of a unit-pricing system might already include the effect of environmental activism. To check this, we test whether municipalities that have introduced a unit-based pricing system in later years (1999 or 2000) already have

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[11] See Milieudefensie of April 1998, www.milieudefensie.nl/blad/1998/april98/twverkie.htm.

[12] Some significant effects were found for vegetable, food and garden (VFG), glass, paper and textiles (GPT) and solid waste, but the coefficients are very small. When the liberal party VVD's share of the vote increases by 10% percentage points, VFG waste increases by only 0.6%. While this increase is very small, the effects of other parties are lower still. Results are available upon request. In other research, we found also very weak evidence that political variables influence the institutional organization of refuse collection (Dijkgraaf, Gradus, & Melenberg, 2003).

[13] This paragraph is based on a suggestion of the referee.

lower waste quantities in the years before introduction. We do this by including a dummy variable that has the value 1 for each municipality with a unit-based pricing system in one or more years of our sample and the value 0 otherwise.[14] Including this activism dummy now corrects for the initial lower level of waste due to environmental activism in municipalities that introduce a unit-based pricing system.

As Table 8.6 shows, the activism dummy is significant for all waste streams. The results indicate that municipalities with a high level of environmental activism have 7% less waste. This means that a significant part of the estimated reduction in waste is due to environmental activism and not to the unit-based pricing system. Municipalities with a high level of environmental activism have 13% less unsorted waste, while the amount of compostable waste is 10% lower. As recyclable waste in such 'green' municipalities is 4% higher, households in municipalities with a unit-based pricing system are more active in sorting their waste regardless of the presence of such a system. Correction for environmental activism results in somewhat lower effects for the frequency-, weight- and bag-based systems, while the effect of the volume-based system on total waste is now insignificant. The environmental-activism dummy is also positive and significant for the estimations with tariffs. The

Table 8.6 Estimation results including environmental activism: dependent is ln(*waste*)

	Total	Unsorted	Compostable	Recyclable
Activism	–0.07	–0.13	–0.10	0.04*
	(0.01)	(–0.02)	(–0.03)	(0.02)
UBP_{weight}	–0.42	–0.56	–0.83	0.15
	(0.03)	(0.04)	(0.06)	(0.03)
$UBP_{bagunscom}$	–0.38	–0.55	–0.83	0.22
	(0.03)	(0.05)	(0.07)	(0.03)
UBP_{baguns}	–0.09	–0.62	0.40	0.12
	(0.02)	(0.03)	(0.05)	(0.03)
UBP_{fre}	–0.18	–0.20	–0.37	0.06
	(0.02)	(0.02)	(0.04)	(0.02)
UBP_{vol}	–0.01#	–0.01#	0.08**	–0.01#
	(0.02)	(0.03)	(0.04)	(0.03)
UBP_{oth}	–0.09	–0.35	0.12*	–0.05#
	(0.03)	(0.04)	(0.07)	(0.05)
R^2 (adjusted)	0.64	0.69	0.64	0.26
F-statistic	77.75	108.02	85.99	17.01
White correction	Yes	No	No	Yes
Fixed effects	Yes	Yes	Yes	Yes
Number of observations	1,323	1,451	1,449	1,334

Note: Equations are estimated including the same socio-economic characteristics as presented in Table 8.4 (results are highly comparable and available on request).

[14] We also include a dummy for each different type of unit-based pricing system. As expected, the activism effect is larger for municipalities with weight- and bag-based systems than for those with the other systems. However, as the change over time is not large for the individual systems, we only present results for the systems together.

estimated price elasticities are, on average, 0.13 smaller for unsorted waste, 0.10 smaller for compostable waste and 0.05 lower for recyclable waste (see Table 8.5).

The activism effect may explain part of the differences found in the literature. For example, the results based on household data in Fullerton & Kinnaman (1996) and Linderhof et al. (2001) will not be biased as they result from a comparison of the same households over different time periods. In this case, the environmental-activism effect is automatically excluded from the estimations. In contrast, studies that rely on cross-section analysis may overestimate the effects of unit-based pricing. This might explain why studies based on aggregate municipality data generally find larger elasticities than studies based on household surveys (see Table 8.1).

8.4 The Effect on Surrounding Municipalities

Section 8.2 shows that unit-based pricing has a significant effect on the total amount of collected waste. The estimations suggest that one of the reasons for this result is that more waste is sorted. However, no attention was paid in that section to adverse behavioral effects. One of these effects is that unit-based pricing systems may introduce incentives for citizens to take their waste to municipalities without unit-based pricing systems. It seems logical to suppose that surrounding municipalities experience waste tourism as social contacts (family, friends) can be used to avoid the pricing system. For example, Linderhof et al. (2001) report a study by the city of Oostzaan, which estimates that about 4–5% of waste is taken to surrounding municipalities (which is approximately 13–17% of the reduction in waste prompted by the introduction of a weight-based pricing system).

To test whether municipalities without unit-based pricing systems collect part of the waste produced in surrounding municipalities with unit-based pricing systems, we estimate the models presented in Table 8.4 including impact factors. These factors measure how many inhabitants in surrounding municipalities have an incentive to take their waste to another municipality. Inhabitants of a municipality with a unit-based pricing system with one or more municipalities in their neighborhood without such a system do have an incentive for this behavior. Impact factors are calculated using the following equation:

$$IF_{s,i} = \sum_{j} \left(\left(1 - \delta D_{i,j}\right) \frac{Inh_j}{Inh_i} S_i \right), \tag{8.2}$$

where $IF_{s,i}$ is the impact factor of municipality i having a unit-based pricing system s, i is a vector of all municipalities, j is a vector of the municipalities with a unit-based pricing system s in the neighborhood of municipality i, δ is a factor between 0 and 1, $D_{i,j}$ is the distance between municipality i and municipality j, Inh_i is the number of inhabitants of municipality i, Inh_j is the number of inhabitants of municipality j and S_i is a dummy with value 0 if municipality i itself has a unit-based pricing system and value 1 if it does not.

The impact factor for municipality i is a function of the distance to and the size of municipalities j (municipalities with unit-based pricing systems). The impact factor is larger when:

1. The distance from a municipality with a unit-based pricing system to a municipality without such a system is smaller. A linear relationship between impact and distance is assumed, while only municipalities with a distance less than 50 kilometers are included, i.e. $\delta = 0.02$ (the impact of municipalities which are more than 50 kilometers away is set to zero). Thus, we assume that taking waste to relatives and acquaintances is less likely if the distance is larger.
2. There are more surrounding municipalities with unit-based pricing systems. If more municipalities with unit-based pricing systems surround a municipality without a unit-based pricing system, the effect will be larger. An extreme example in the Netherlands is Helmond, which does not have a unit-based pricing system and which borders 7 municipalities that have unit-based pricing systems and has 40 municipalities with unit-based pricing systems within a distance of 50 kilometers. On the other hand, 13 municipalities do not have any municipalities with unit-based pricing systems within this distance (consequently, their impact factors are 0). On average, a municipality without a unit-based pricing system has 6 municipalities with unit-based pricing systems in its vicinity.
3. A surrounding municipality with a unit-based pricing system is larger. A surrounding municipality with a unit-based pricing system having the same number as a neighboring municipality without a unit-based pricing system will have less effect on the quantity of waste collected in this latter municipality than will a municipality with 10 times as many inhabitants.

The impact factor is 0 when municipality i itself has a unit-based pricing system. The impact factors are calculated for the different unit-based pricing systems s. For example, $IF_{weight,i}$ is a measure of the impact on collected waste in a municipality without a unit-based pricing system of surrounding municipalities with a weight-based system. Table 8.7 presents the means and standard deviations of the impact factors.

As is shown in Table 8.7, the estimations give little indication of a significant effect from waste tourism. Only 4 out of 20 coefficients are positive and significant, while the size of these coefficients is very small. Furthermore, 3 of the 4 coefficients for the weight-based system are insignificant at 90%, while this system is expected to have the largest effect on surrounding municipalities (evaluated at the mean, the significant effect of the weight-based system is an increase of only 0.6% in the quantity of collected unsorted waste).

To test for misspecification, we also estimated with a non-linear impact factor (decreasing with distance) omitting the scale effect. In this case, only two coefficients are significant. Other estimations also produce few significant coefficients.[15]

[15] We estimated models including impact factors calculated with higher ($\delta = 0.013$ and maximum distance of 75 kilometers) or lower ($\delta = 0.04$ and maximum distance of 25 kilometers) influence from neighboring municipalities, impact factors that are only 0 if the same unit-based pricing

Table 8.7 Estimation results: models with impact factors

	Descriptive statistics		Effect of impact variables on ln(Waste)			
	Mean	St. dev.	Total	Unsorted	Compostable	Recyclable
IF_{weight}	0.19	0.44	0.012#	0.028**	0.034#	0.016#
			(0.007)	(0.012)	(0.021)	(0.018)
IF_{bag}	0.86	2.93	–0.001#	0.003#	–0.004#	–0.010*
			(0.001)	(0.002)	(0.003)	(0.005)
IF_{fre}	0.59	2.00	–0.002#	–0.012	0.000#	0.009**
			(0.001)	(0.003)	(0.005)	(0.004)
IF_{vol}	1.02	2.35	0.000#	–0.000	–0.002#	–0.003#
			(0.001)	(0.002)	(0.004)	(0.005)
IF_{oth}	0.29	0.84	0.010	0.007#	0.041	–0.009#
			(0.003)	(0.006)	(0.010)	(0.007)

Note: Equations are estimated including the same socio-economic characteristics as presented in Table 8.4 (results are highly comparable and available on request).

Therefore, we conclude that the taking of waste to municipalities without unit-based pricing systems is relatively unimportant in the Netherlands.

8.5 Administrative Costs and Illegal Dumping

Section 8.2 shows that the effectiveness of bag-based pricing is comparable to that of weight-based pricing. This is an interesting result because the administrative costs for bag-based pricing are much lower. VROM (1997) evaluates weight-, bag- and frequency-based pricing systems in 12 Dutch municipalities.[16] According to this study, average administrative costs are higher for the weight-based pricing system (6.86 euro per inhabitant) than for the other systems (3.18 euro for the bag-based system, 4.28 euro for the frequency-based system).

Given the large reductions in unsorted waste, municipalities can save a lot of money by introducing (especially) a bag-based pricing system. For example, the saving in disposal costs is 5 euro per inhabitant larger than the rise in administrative costs for the bag-based system.[17]

The introduction of unit-based pricing systems may, however, have adverse effects. Citizens may take their waste to neighboring municipalities or may dump

system applies and the environmental-activism dummy. As there was no clear pattern in the results, except that the estimations give insignificant coefficients for nearly all impact variables, we only present the results of estimations with the scale-related linear impact factors with $\delta = 0.02$. Other results are available on request.

[16] The administrative costs for 1997 are given in 2000 prices.

[17] This calculation is based on the cost of incineration (the cheapest available and allowed option in the Netherlands). According to Dijkgraaf, Aalbers, and Varkevisser (2001), total cost per tonne for an efficient incineration plant built in accordance with European law is 77 euro per tonne. Furthermore, VROM (1997) shows that only 2 municipalities (with frequency-based systems) report savings in disposal costs smaller than the rise in administrative costs.

their waste illegally. Analysis of the behavior of Dutch citizens in Section 8.4 shows that there is no evidence that surrounding municipalities without unit-based pricing systems in fact collect part of the waste produced in municipalities with unit-based pricing systems. The evidence on illegal dumping is more mixed. Some studies give support for the hypothesis that illegal dumping is an important issue. Fullerton & Kinnaman (1996) estimate that illegal dumping constitutes 28% of the total reduction in waste collected at the curb. Hong (1999) shows that dumping was substantial after the adoption of the unit-based pricing system in Korea. On the other hand, Reschovsky & Stone (1994) find no relation between illegal dumping and unit-based pricing, while Van Houtven & Morris (1999) report that 'officials ... found little to no evidence of more littering or increased use of accessible dumpsters.'

For the Netherlands, Linderhof et al. (2001) state that illegal dumping is virtually non-existent in Oostzaan. According to them, the monitoring system in Oostzaan, with fines for illegal dumping, appears to be very effective in terms of deterrence. Moreover, another explanation for the absence of illegal dumping is that a small municipality such as Oostzaan has a large degree of social control. In general, the high population density of the Netherlands would suggest a low level of illegal dumping compared with other countries. This is confirmed by the lack of clear anecdotal evidence despite the large number of municipalities with unit-based pricing. However, as the main disadvantage of unit-based pricing systems is the potential effect on illegal dumping, it seems worthwhile investigating an effective monitoring and fining system and the conditions under which such a system would work.

8.6 Conclusions

This chapter provides an empirical analysis of the effects of unit-based pricing of household waste for the Netherlands. We find that the weight- and bag-based pricing systems perform far better than the frequency- and volume-based pricing systems. The bag-based system seems to be the best option, as its effects are comparable to those of the weight-based system and yet its administrative costs are far lower.

Compared with the elasticities found in the literature, the estimated Dutch own-price elasticities for the bag-based and weight-based systems are high. The higher elasticities are not the result of higher marginal tariffs in the Netherlands or of higher cross-price elasticities. A possible explanation might be that more waste is taken to other municipalities (without unit-based pricing systems). However, statistical analysis does not provide evidence that neighboring municipalities do collect part of the waste of municipalities that have unit-based pricing systems. Another possibility is that more waste is illegally dumped. Unfortunately, we have no data with which to estimate the effects on illegal dumping. Monitoring and fining may be important to deter this behavior Given the high population density of the Netherlands and the lack of anecdotal evidence, it seems implausible that a large part of the reduction in unsorted waste is due to illegal dumping.

Therefore, it seems likely that the introduction of unit-based pricing results in a significant change in citizens' behavior. Analysis of the waste quantities before and after introduction of a unit-based pricing system shows that environmental activism does play a role. Waste quantities are lower in municipalities that introduce unit-based pricing in later years. Thus the estimated effects of unit-based pricing may overestimate the effects of unit-based pricing when it is introduced in 'green' municipalities. On average, the estimated price elasticities are 0.13 smaller for unsorted waste, 0.10 smaller for compostable waste and 0.05 lower for recyclable waste when we correct for the environmental-activism effect. However, for municipalities with a low level of environmental activism, the estimated effects based on the dummy-variable approach may be applicable, as introduction of a unit-based pricing system internalizes the lack of environmental activism.

Furthermore, this chapter illustrates that refining unit-based pricing results in greater reductions in collected waste. A simple explanation of why the estimated elasticities for the bag-based system are higher in the Netherlands than elsewhere might be the significantly smaller volume of the bags used (50–60 liters or 13–16 gallons) compared with those in the USA (113–121 liters or 30–32 gallons). That this might be an important issue is indicated by the estimated elasticities of the frequency-based system. While the volume of the Dutch cans in the frequency-based system is comparable to that of the bags in the USA, the estimated Dutch elasticities for the frequency system are also comparable to the elasticities found for the bag program in the USA. Furthermore, the relatively small volume of the Dutch bags might explain why weight-based systems have comparable elasticities.

The smaller bag volume may explain why elasticities for the bag-based system are higher in the Netherlands, but not how Dutch citizens manage to achieve such large decreases in waste as estimated in this chapter. Detailed case studies might be necessary in order to generate enough information to get a grasp of the changes in citizens' behavior when they are confronted with marginal pricing.

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Appendix: Definition of Variables

$Waste_{total}$	Annual total waste collected, in kilograms per inhabitant (sum of unsorted, compostable and recyclable waste) (logged)
$Waste_{unsorted}$	Annual unsorted waste collected, in kilograms per inhabitant (logged)
$Waste_{compostable}$	Annual compostable waste collected, in kilograms per inhabitant (logged)
$Waste_{recyclable}$	Annual recyclable waste (glass, paper and textiles) collected, in kilograms per inhabitant (logged)
UBP_{weight}	Dummy = 1 if municipality has a weight-based pricing system
$UBP_{bagunscom}$	Dummy = 1 if municipality has a bag-based pricing system for both unsorted and compostable waste
UBP_{baguns}	Dummy = 1 if municipality has a bag-based pricing system for unsorted waste
UBP_{fre}	Dummy = 1 if municipality has a frequency-based pricing system
UBP_{vol}	Dummy = 1 if municipality has a volume-based pricing system
UBP_{oth}	Dummy = 1 if municipality has an unspecified type of pricing system
Retire	Percentage of inhabitants older than 65 (logged)
Fam size	Number of inhabitants per household (logged)
Foreigner	Number of non-western foreigners per inhabitant (logged)
City	Dummy = 1 if municipality has more than 100,000 inhabitants
Village	Dummy = 1 if municipality has less than 20,000 inhabitants
Density	Area of municipality, in hectares per inhabitant (logged)
Own_{house}	Number of houses sold per 1000 inhabitants
Own_{flat}	Number of flats sold per 1000 inhabitants
Income	Percentage of inhabitants with income over 12,400 and under 21,400 euro (logged)
IF_{weight}	Impact factor measuring surrounding municipalities with weight-based pricing
IF_{bag}	Impact factor measuring surrounding municipalities with bag-based pricing
IF_{fre}	Impact factor measuring surrounding municipalities with frequency-based pricing
IF_{vol}	Impact factor measuring surrounding municipalities with volume-based pricing
IF_{oth}	Impact factor measuring surrounding municipalities with unspecified type of pricing
Activism	Environmental activism dummy with value 1 for each municipality with a unit-based pricing system in one or more years of our sample and value 0 otherwise.

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