COST SAVINGS OF UNIT-BASED PRICING OF HOUSEHOLD WASTE

The case of the Netherlands*

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Using a panel data set for Dutch municipalities we estimate effects for weight-based, bag-based, frequency-based and volume-based pricing of household waste collection. Unit-based pricing shows to be effective in reducing solid and compostable and increasing recyclable waste. Pricing has no effect on the waste collected in surrounding municipalities (waste tourism). However, unit-based pricing may lead to illegal dumping. While empirical evidence is scarce, a social cost-benefit analysis shows that if the social valuation of illegal dumping is in line with the social costs for collecting and treating solid waste, the weight or bag-based systems are preferable.

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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 container presented at the curb for collection. In 2000 more than 20% of all Dutch municipalities have implemented such a system. In this paper we estimate household reactions to the implementation of unit-based pricing for the collection of residential waste. Our estimates show significant and sizeable price effects.

In the literature two lines of thought can be distinguished, which estimate household reactions to the implementation of unit-based pricing systems. A first stream of literature uses cross-sections analyses of municipalities (e.g. Wertz (1976), Jenkins (1993), Podolsky and Speigel (1998), Kinnaman and Fullerton (1997)). A second stream of literature tries to use household survey data (e.g. Hong et al. (1993), Reschovky and Stone (1994), Fullerton and Kinnaman (1996), Linderhof et al. (2001)). Most of the studies show considerable impact of a pricing system.

Recently, Linderhof et al. (2001) published the effects of weight-based pricing for Oostzaan, the first Dutch municipality that implemented weight-based pricing in 1993. They find significant price effects and conclude that the implementation yields significant social benefits. They show that weight-based pricing is effective in reducing especially compostable waste (vegetable, fruit and garden waste) and increasing recyclable waste (glass, textile and paper). One question, which is raised, is how representative Oostzaan is to the rest of the country. In this article we will show that Oostzaan is rather representative and, therefore, unit-based pricing can be rather effective for the Netherlands.

We extend the literature in four directions. Firstly, we distinguish between different systems of unit-based pricing such as weight-based, bag-based, frequency-based and volume-based pricing. It is interesting to investigate other systems than weight-based systems as well, because the administrative costs and adverse effects like illegal dumping - two of the disadvantages of weight-based pricing - are much lower. Secondly, we investigate whether the political affiliation of a municipality is important for the size of the price effect. In earlier research we found only very weak evidence that political variables have influence on the institutional organization of refuse collection (Dijkgraaf et al., forthcoming). Thirdly, we test whether surrounding municipalities without a pricing system in fact collect part of the waste produced in municipalities with a unit-based pricing system. Finally, the paper concludes with a social cost-benefit analysis. Based on the estimated effects on the quantity of collected waste, we evaluate whether the different systems are beneficial and which system performs best from a social perspective. Not only the administrative costs, but also the effects on collection, treatment, dumping and environmental costs are included. It is shown that the social valuation of the effect on illegally dumped waste is essential for a proper analysis of the value of unit-based pricing systems.

2. Effects of unit-based pricing

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 e.g. Fullerton and Kinnaman, 1996).

We use the quantity of collected waste (in kilogram per inhabitant) as the dependent variable. However, we are able to discriminate between different waste streams. In the Netherlands two types of waste are collected separately at curbside: compostable waste such as vegetables, food and garden waste (VFG) and non-recyclable (or solid) waste. Furthermore, a number of recyclable materials such as glass, paper and textile (GPT) can be brought to special containers.[2] The use of these containers is free of charge. In a survey of the Dutch Waste Management Council (AOO), weighing data on solid, compostable and recyclable waste are given for each municipality. Thus, we use not only total collected waste (per inhabitant) as the dependent variable, but also its components: solid, VFG and GPT waste.

In our data set there is information available about the price system. Therefore, we included five dummies for the institutional form in which the price system is arranged, depending on whether the tariff is based on:

- the weight of the garbage;
- the number of collected bags;
- the frequency of collection and the volume of the container;
- the volume of the container;
- other or mixed systems.

Table 1. Number of municipalities with price system

	1998	1999	2000
Weight	9	10	13
Bag	21	20	22
Volume and frequency	20	43	53
Volume	24	27	24
Other differentiated	6	8	10
Total differentiated	80	108	122
Total flat rate	458	430	416
Total	538	538	538

[2] In some municipalities there is a free curbside collection program for recyclable paper organized by local associations, such as sport clubs. Furthermore, most municipalities have a possibility for free collection of small quantities of chemical waste or tins as well. Due to the fact that this stream is very small it is not taken into account.

Table 1 clearly shows that the number of Dutch municipalities with unit-based pricing is increasing. In 2000 23% of Dutch municipalities has a unit-based pricing system. Although increasing, the number of municipalities with weight-based pricing is relatively small. Maybe the administrative costs and potential effects on illegal dumping are for many municipalities a reason not to implement such a system. In contrast, the number of municipalities with unit-based pricing based on the volume of the container and the frequency of collection has increased in recent years. The number of municipalities with unit-based pricing only based on volume has stayed constant over recent years. As will be shown later on, this system is relatively ineffective in reducing the generation of waste. Furthermore, in 2000 10 municipalities have a mixed system due to changes in boundaries between municipalities. Although the number of municipalities using a unit-based pricing system is increasing, still the main part of the municipalities uses a flat tax.

Furthermore, to correct for differences between the municipalities we include the following control variables:

- the area of a municipality per inhabitant and its square (expected effect positive, especially for VFG waste);
- the size of the average family (expected sign negative as larger family size probably leads to less waste per inhabitant due to scale effects);
- the percentage of non-western foreigners (expected sign negative);
- the average income per inhabitant (expected sign positive);
- houses owned per inhabitant (expected sign positive);
- flats owned per inhabitant (expected sign negative, especially for VFG waste)
- a dummy for small municipalities (expected sign positive as small municipalities produce generally more waste per inhabitant);
- a dummy for large cities (expected sign negative for the opposite reason);
- the percentage of retired people (expected sign unknown).

These data come from the CBS (the Dutch Central Bureau for Statistics). In table 2 the descriptive statistics for the variables are given (see the appendix for the variable definition).[3]

[3] In our dataset nearly all Dutch municipalities (538 in 2000) are included. The actual number of municipalities included differs per dependent variable due to data availability (see table 2).

As data were available for 1998 till 2000 we estimate a panel model using both the cross-section as the time related variation.[4] To correct for differences not captured by the control variables we include both fixed year and cross-section effects.[5]

Table 2. Descriptive statistics data

	Mean	Maximum	Minimum	Std. Dev.	Number of observations	Number of cross sections
$Waste_{tot}$	431	707	222	62	1323	507
$Waste_{sol}$	218	450	52	54	1451	530
$Waste_{vfg}$	117	239	12	39	1449	529
$Waste_{gpt}$	99	217	19	20	1334	508
$Diftar_{weight}$	0.02	1.00	0.00	0.14	1451	530
$Diftar_{bag}$	0.04	1.00	0.00	0.18	1451	530
$Diftar_{volfre}$	0.07	1.00	0.00	0.26	1451	530
$Diftar_{vol}$	0.04	1.00	0.00	0.20	1451	530
$Diftar_{oth}$	0.01	1.00	0.00	0.12	1451	530
Retire	0.13	0.28	0.06	0.03	1451	530
Fam size	2.56	3.70	1.72	0.20	1451	530
Foreigner	0.04	0.31	0.00	0.04	1451	530
City	0.05	1.00	0.00	0.22	1451	530
Village	0.57	1.00	0.00	0.50	1451	530
Density	0.50	27.46	0.02	1.35	1451	530
Own_{house}	10.05	30.59	1.34	3.12	1451	530
Own_{flat}	1.68	16.53	0.00	2.20	1451	530
Income	39.04	44.60	28.50	2.34	1451	530
$Impact_{weight}$	0.19	4.67	0.00	0.44	1451	530
$Impact_{bag}$	0.86	37.37	0.00	2.93	1451	530
$Impact_{volfre}$	0.59	39.94	0.00	2.00	1451	530
$Impact_{vol}$	1.02	23.30	0.00	2.35	1451	530
$Impact_{oth}$	0.29	10.81	0.00	0.84	1451	530

4 We tested the assumption that pooling with respect to the different years is allowed. An F-test on the sum of squared residuals rejected this assumption on 99% (F-statistic is 2.04, 24 restrictions, 1299 degrees of freedom). However, as the test statistic is near the level of significance (1.80) and the results for the most interesting variables are rather robust, we only present the results based on the pooled estimations.

5 Ideally we want to include a fixed-effect per 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 per province. Results for the fixed effects are available upon request.

2.2 Results

Table 3 presents the estimation results.[6,7] The F-statistics show that the equations are significant, while the relatively high (adjusted) R^2 indicate that the explained variation is not small.

Table 3. Estimation results

	$\log(Waste_{tot})$	$\log(Waste_{sol})$	$\log(Waste_{vfg})$	$\log(Waste_{gpt})$
$Diftar_{weight}$	-0.48	-0.68	-0.95	0.19
	(0.02)	(0.03)	(0.05)	(0.03)
$Diftar_{bag}$	-0.24	-0.72	-0.07^{*}	0.19
	(0.02)	(0.02)	(0.04)	(0.02)
$Diftar_{volfre}$	-0.24	-0.31	-0.47	0.09
	(0.01)	(0.02)	(0.03)	(0.02)
$Diftar_{vol}$	-0.07	-0.13	$-0.03^{\#}$	$0.02^{\#}$
	(0.02)	(0.02)	(0.03)	(0.02)
$Diftar_{oth}$	-0.16	-0.48	$-0.00^{\#}$	$-0.01^{\#}$
	(0.03)	(0.04)	(0.06)	(0.05)
log(Retire)	0.12	$0.04^{\#}$	0.32	0.08^{*}
	(0.02)	(0.03)	(0.06)	(0.04)
log(Fam size)	-0.21^{**}	-0.62	0.66	0.31^{*}
	(0.08)	(0.11)	(0.19)	(0.16)
log(Foreigner)	-0.04	$-0.00^{\#}$	-0.11	-0.02^{*}
	(0.01)	(0.01)	(0.02)	(0.01)

6 We tested all specifications for heteroskedasticity using the Breusch-Pagan test. It showed that for estimations with the independent variables in levels nearly always heteroskedasticity could not be rejected. Therefore we estimate in logs. In cases where heteroskedasticity could still not be rejected, we corrected the standard errors with the White-procedure (see table 3).

7 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 (like the percentage of inhabitants with full-time work, the percentage of western foreigners, the number of families with 1, 2 or more children, paid property tax and the size of the agriculture sector) shows 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 system and between –0.23 and –0.26 for the bag-system and the volume and frequency system. Further results are available upon request.

	$\log(Waste_{tot})$	$\log(Waste_{sol})$	$\log(Waste_{vfg})$	$\log(Waste_{gpt})$
City	-0.04	0.01[#]	-0.21	-0.16
	(0.01)	(0.02)	(0.04)	(0.03)
Village	0.02[**]	-0.03	0.08	0.05
	(0.01)	(0.01)	(0.02)	(0.02)
log(Density)	0.03	0.09	0.02[#]	0.00[#]
	(0.01)	(0.01)	(0.02)	(0.03)
$\log(Density)^2$	0.004[*]	0.028	-0.013	0.002[#]
	(0.002)	(0.003)	(0.005)	(0.009)
Own_{house}	0.002[*]	0.003[*]	0.014	0.002[#]
	(0.001)	(0.002)	(0.003)	(0.002)
Own_{flat}	-0.007	0.000[#]	-0.025	-0.013
	(0.002)	(0.002)	(0.004)	(0.004)
log(Income)	0.27	0.24	0.07[#]	0.26[#]
	(0.06)	(0.09)	(0.15)	(0.17)
R^2 (adjusted)	0.60	0.68	0.57	0.26
F-statistic	71.48	110.08	69.12	17.92
White-correction	Yes	No	No	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	1323	1451	1449	1334

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

First, the estimations for the price system dummies will be discussed. Pricing waste on the basis of its weight has a highly negative and significant effect on total waste of 38%.[8] This effect differs for the underlying waste streams. Compostable waste diminishes with more than 60%. It seems that many Dutch households use home composting methods to lower this type of waste.[9] Also the effect on solid waste is large. Introducing a weighing system reduces the amount by nearly 50%. Many behavioral effects could lie behind these strong effects on the amount of waste presented for collection. From the estimations it is clear that one of the important mechanisms generating these results is that the amount of GPT waste increases when a unit-based

8 As the dependent variable is in logs the effects of the pricing dummies are calculated using e^x-1, with x the estimated coefficient.

9 By introducing a weighing system some municipalities stimulate home composting by subsidizing the purchase of home compost containers (see Linderhof et al., 2001).

pricing system is introduced. Clearly, introducing the weight-based system leads to higher efforts for recycling glass, paper and textiles (plus 21%). Of course this is due to the fact that Dutch citizens do not have to pay for the collection of this waste.

As expected, the effects of the other unit-based pricing systems are smaller. Introducing a bag-based pricing system reduces the amount of total waste by 21%, mainly due to less solid waste (51%). As the bag-based system leaves VFG waste - as far as can be checked - unpriced, the effect of this system on VFG waste is small and insignificant at 95%. Interestingly, the collection of GPT waste rises also with 21%, reassuring the assumption that households invest more in sorting their waste.

The system based on frequency and volume reduces the total amount of waste by 21%, both due to a reduction of solid waste (27%) and VFG waste (38%). As the effects on solid waste are less pronounced, the stimulating effect on the collection of GPT waste is smaller (9%) as well.

Less clear are the effects of introducing a system only based on the volume of the container. Total waste decreases with only 7%, mainly due to the effect on solid waste. Because there is no marginal pricing of extra waste, this is not surprising.

Some of the control variables are interesting to look at. As suggested by the literature we find economies of scale for total waste. An increase in household size from 2 to 3 is found to reduce collected waste per inhabitant by 22,5%. Interestingly, there are diseconomies of scale for compostable waste. A possible explanation is that households with three or more persons have a larger chance to have a garden, while the amount of compostable waste is primarily determined by the existence of garden area.

Moreover, for municipalities with a larger population of elderly or a smaller population of foreign people the amount of waste per capita is larger. 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 for the municipalities with many flats is negative for compostable waste. Moreover, more area in hectare per inhabitant increases the waste stream. The coefficient on income for total and solid waste is in accordance with the literature and positive, while income has no influence on VFG and GPT waste.

3. Some further discussion of the results

3.1 The price elasticities of the weight-based system

In section 2 we estimated the effects of unit-based pricing systems using dummies for the different systems. However, more specific information on tariffs is available for the weight-based pricing system. This makes it possible to evaluate whether the approach leads to significant other results than using marginal prices.

Estimating the same equations as presented in table 3, but now with the marginal price substituted for the weight dummy, results in price coefficients of -1.34 (total waste), -1.91 (solid waste), -2.64 (VFG waste) and 0.50 (GPT waste). All coefficients are significant at 99%.[10] The implied elasticities evaluated at the sample means are -0.48, -0.69, -0.96 and 0.18.

The results for the elasticities are in line with Linderhof et al. (2001), although their elasticities for VFG (-1.39 (long run) and -1.10 (short run)) are above our results. As suggested by Linderhof et al. (2001) a possible explanation could be that the extensive public debate in Oostzaan boosted environmental awareness for VFG.

It seems that the elasticities in Dutch studies are larger than those in US studies on unit-based pricing. In a recent overview Kinnaman and Fullerton (1999) show that the price elasticities of unit-based pricing are between -0.1 and -0.4. Comparing these results with our weight system elasticity of –0.48 for total waste, it should be noticed that these studies also include other unit-based pricing systems which are of course less ineffective for marginal price setting. Nevertheless, there seems room for the impression that Dutch citizens are more environmentally conscious.

3.2 The importance of political variables

Linderhof et al. (2001) suggest that they possibly underestimate the effects of the weight-based system due to the political affiliation of Oostzaan: its citizens seem to be more than average environmentally conscious.[11] However, they show that in the first year after the introduction of the weight-based pricing the amount of waste decreased with 30% and in the long run with 40%. As this result is comparable to the estimated effect of weight-based pricing systems in all Dutch municipalities, the political effect could be doubted.

A more rigorous way to check political influence is to include the fractions of political parties based on the local election of March 1998 in the estimations presented in table 3. However, this shows that none of the Dutch political parties has a significant influence on the total amount of waste.[12] Also in other research we found only very weak evidence that political variables have influence on the institutional organization of refuse collection (Dijkgraaf et al., forthcoming).

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10 The results for the other variables are very close to table 3, which gives a further indication of the robustness of our results. Results are available on request.

11 The largest political party in Oostzaan is Green Left (38% of total votes), which is the most environmentally friendly oriented political party in the Netherlands. Green Left received nation-wide only 7% of the votes in the parliamentary elections of 1998.

12 Some significant effects were found for solid, VFG and GPT waste, but coefficients are very small. When the liberal party VVD grows with 10% in votes, VFG waste increases with only 0.6%. While this increase is very small, the effects of other parties are still much lower. Results are available upon request.

3.3 Is there an effect on surrounding municipalities?

In section 2 we show that unit-based pricing has a significant effect on the total amount of collected waste. The estimations show that one of the reasons for this result is that more waste is sorted. However, no attention was paid to adverse behavioral effects. One of these effects is that unit-based pricing systems may introduce incentives to bring the waste to other municipalities without a unit-based pricing system. It seems logical to suppose that surrounding municipalities experience waste tourism as social contacts (family, friends) can be used to avoid the pricing system.

To test whether municipalities collect part of the waste produced in surrounding municipalities with a unit-based pricing system, we estimate the models presented in table 3 including the following impact factors:

$$IF_{s,i} = \sum_j (1 - 0.02 D_{i,j}) * \frac{Inh_j}{Inh_i} * S_i \qquad (1)$$

with:

- $IF_{s,i}$ Impact factor of municipality i of unit-based pricing system s
- $D_{i,j}$ Distance between municipality i and municipality j
- Inh_i Number of inhabitants of municipality i
- Inh_j Number of inhabitants of municipality j
- S_i Dummy with value 0 if municipality i itself has a unit-based pricing system.

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

(i) The distance from a municipality with a unit-based pricing system to a municipality without such a system is smaller (assumed is a linear relation between impact and distance while only municipalities with a distance less than 50 kilometers are included). Thus, we assume that bringing waste to relatives and acquaintances will be less interesting if the distance is larger.

(ii) There are more surrounding municipalities with a unit-based pricing system. The distance from each municipality with a unit-based pricing system (when this distance is less than 50 kilometers) is included.

(iii) A surrounding municipality is larger. A municipality introducing a unit-based pricing system with the same number of inhabitants as a surrounding municipality will have less influence on the collected quantity of waste on this last municipality than a municipality with 10 times as many inhabitants.

The impact factor is zero when municipality i has itself 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 for the impact on collected waste in a municipality without a unit-based system of surrounding municipalities with a weight-based system.

Table 4. Estimation results models with impact factors

	$\log(Waste_{tot})$	$\log(Waste_{sol})$	$\log(Waste_{vfg})$	$\log(Waste_{gpt})$
IF_{weight}	0.01#	0.03**	0.03#	0.02#
	(0.01)	(0.01)	(0.02)	(0.02)
IF_{bag}	-0.00#	0.00#	-0.00#	-0.01*
	(0.00)	(0.00)	(0.00)	(0.01)
IF_{volfre}	-0.00#	-0.01	0.00#	0.01**
	(0.00)	(0.00)	(0.01)	(0.00)
IF_{vol}	0.00#	-0.00	-0.00#	-0.00#
	(0.00)	(0.00)	(0.00)	(0.00)
IF_{oth}	0.01	0.01#	0.04	-0.01#
	(0.00)	(0.01)	(0.01)	(0.01)

Notes: Equations are estimated with the specifications presented in table 3. Results for other coefficients available on request. Standard errors in parenthesis. All coefficients are significant at the 99% confidence interval, except for coefficients with **(*) which denotes significance at the 95(90) percent level and for coefficients with # which denotes non-significance at the usual levels.

As is shown in table 4 the estimations give little indication for a significant effect of municipalities with a unit-based pricing system on surrounding municipalities without such a system. Only four coefficients are positive and significant. Furthermore, three of the four coefficients of the weight-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-system is only 0.6% on the quantity of collected solid waste).

To test for misspecification, we estimated also with a non-linear impact factor (decreasing with distance) skipping the scale effect. In this case only two coefficients are significant. Also other estimations, for example with impact factors, which are only zero if the same unit-based pricing system applies, produce few significant coefficients.[13] Therefore, we conclude that bringing waste to municipalities without a unit-based pricing system is relative unimportant in the Netherlands.

3.4 Illegal dumping

The results of section 2 show that the implementation of the unit-based pricing system has strong effects on the amount of waste presented for collection. In the preceding section we showed that these effects are not related to bringing waste to municipalities without a unit-based pricing system. In this section the effect of illegal dumping is investigated.

[13] As there was also no clear pattern in the results, except that most estimations result in insignificant variables, only the effects with the scale related linear impact factor are presented. Results are available on request.

Fullerton and Kinnaman (1996) state that a unit-based pricing system provides pervasive incentives for households to dump waste illegally and thus incurs extra environmental costs. Newspaper articles are reported which imply that dumping had been substantial after the adoption of a unit-based pricing system in Charlottesville, Virginia. However, official statistics are not available. Therefore, they use a method of estimating the amount of illegal dumping by suspecting illegal dumping if the amount of waste fell to zero for a four-week period and the household indicated that "other" means were used to reduce waste. Based on this method they estimate that illegal dumping constitutes 28% of the total reduction in waste at the curb.

Linderhof et al (2001) reports a study by the city of Oostzaan, which estimates that about 4-5% of the waste is brought to surrounding municipalities (which is approximately 13-17 % of the reduction). Furthermore, it was stated that illegal dumping is virtually non-existent.
According to Linderhof et al. (2001) the monitoring system in Oostzaan, with fining 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 as Oostzaan has a large degree of social control.

However, Hong (1999) shows that dumping had been substantial after the adoption of the unit-based pricing system in Korea. Therefore, it is important to get more information about the size and social costs of illegal dumping to understand household solid waste management. In the next section it is shown that the attitude of society towards illegal dumping is very important for valuing the unit-based pricing systems.

3.5 The social costs and benefits of volume pricing

In this section we present a social cost-benefit analysis of the different systems compared to a flat tax system. Hereby, we quantify direct private costs such as collection and treatment costs and indirect environmental costs such as emissions and dumping costs. By including such costs the literature is extended.

From a welfare point of view a number of effects are important with respect to the evaluation of unit-based pricing systems:

1. The change in collection costs due to the effect on the collected quantity.
2. The change in treatment costs due to the effect on the collected quantity.
3. The change in administrative costs due to the introduction and maintenance of the unit-based pricing system.
4. The social costs of extra illegal dumping due to the introduction of unit-based pricing system.

Table 5 summarizes the collection and treatment costs per ton waste. As we are interested in the welfare effects of the different systems not only the out of pocket costs (private costs) are important, but also the effects on the environment of collection and treatment.

Table 5. Social costs collection and treatment in euro per ton

	Solid	VFG	GPT
Private collection costs	41	41	5
Private transport costs	30	30	30
Private treatment costs	91	49	-53
Total private costs	162	120	-18
Environmental collection costs	0	0	0
Environmental transport costs	1	0	0
Environmental treatment costs	18	9	-173
Total environmental costs	19	10	-173
Total social costs	180	129	-191

The table shows that the private collection costs are the same for solid and VFG waste. Thus, if a unit-based pricing system results in a decrease of total collection of one ton solid (or VFG) waste the total private collection costs diminish with 41 euro. However, as it is not reasonable to assume that a linear relationship exists between collected quantity of waste and total costs (because the same number of pickup-points remain), we assume that municipalities receive only 50% of this reduction in collection costs. As the collection infrastructure for GPT waste is based on a bring-system the private collection costs are much lower. The transport costs (including costs for transshipment) are the same for all types of waste. Here it is reasonable to assume that transport costs change linear with the quantity collected.

Environmental collection costs are related to the effects of transport on the environment. If a unit-based pricing system results in less collection the environment is better off due to less emissions of the collection vehicle. However, as the average transport distance is not very high (less than 40 kilometers, based on EC (2001)), the total environmental collection costs are relatively low (at an estimated cost of 0.10 euro per tonkm, based on CE (1999)). Private treatment costs, which are based on the average Dutch costs, do differ between the different options (see Dijkgraaf et al., 1999 and 2001). Incineration of solid waste is the most expensive option (91 euro per ton), while recycling of GPT has a negative cost of 53 euro per ton (mostly due to the benefits of paper recycling).[14]

The estimated environmental costs are dominated by emissions to air, water and bottom and the effects of the resulting chemical waste after treatment (Dijkgraaf and Vollebergh, 1998). Following Brisson (1997) composting waste results in less environmental costs than incineration while WS (2000) presents negative costs for recycling of GPT. This last figure is possible because the environmental costs of the

[14] In the Netherlands hardly any solid waste from households is landfilled due to a landfill ban and tax (75 euro per ton).

recycling process are much smaller than the environmental benefits due to saved emissions by the production of virgin materials.
The system costs of the different unit-based pricing systems are based on an overview of evaluated systems in Dutch municipalities (VROM, 1997).[15] As municipalities differ with respect to system costs, these costs are calculated as the average of the municipality with the cheapest cost per system and the most expensive municipality. As could be expected the weight-based pricing system is more expensive (8.11 euro per inhabitant) than the other systems (4.12 euro for the bag system, 6.54 euro for the volume and frequency system and 4.36 euro for the volume system).

The previous section gives the information needed to calculate the effects of unit-based pricing on social costs. Table 6 presents the results. The weight-based and bag-based systems perform best in terms of environmental costs. It should be noticed that the weight-based and the bag-based system decrease the amount of solid waste with large environmental costs substantially and increase the amount of recyclable waste with high environmental benefits also substantially. From the view of private costs the weight-based system performs better than the other systems. The reason for this is the higher savings on collected waste. Therefore, in social terms the weight-based system performs slightly better than the bag-based system. Moreover, the volume and frequency system performs better than the flat rate and the volume system is even worse, although the differences are rather small.

Table 6. Total costs per system (level for flat-rate and change for other systems)

Costs	Flat rate (level)	Weight (change)	Bag (change)	Vol. and Freq. (change)	Volume (change)
Total private costs	45	-14	-12	-6	+1
Total environmental costs	-12	-6	-6	-3	-0
Total social costs	33	-20	-18	-9	+0

In table 6 the effect on illegal dumping is not included. However, as the political debate is most concerned about this issue, it is important to get hold on the effect of this issue. First of all, the effect of unit-based pricing systems on the quantity of illegally dumped waste is important. As a basis we use the figure of Fullerton and Kinnaman (1996) who estimate that 28% of the decrease in waste leaks away. We assume that the illegal effect is linear to the reduction in waste of a specific unit-based pricing system. Thus, the illegal effect is the highest for the weight-based system (28%) and the lowest for the volume system (6%).[16]

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15 The administrative costs for 1997 are given in 2000 prices.

16 Of course different figures for these effects are estimated in the literature. However, the uncertainty in these effects is captured in the different shadow prices we use for the estimation of the effect of illegal dumping in monetary terms.

The costs of illegal dumping are harder to obtain. One possible method is to estimate the costs of collection and treatment of illegally dumped waste. Another method is to use a willingness to pay price for people to accept the littering of their environment. Unfortunately, for both methods no real figures are available. We therefore show whether the main results of table 6 are robust for different levels of the willingness to pay for illegally dumped waste (the 'shadow price').

Table 7. Total change in social costs per system

Shadow price illegal dumping	Weight	Bag	Vol. And Freq.	Volume
0	-20	-18	-9	0
50	-18	-17	-8	0
100	-17	-16	-8	1
181	-15	-14	-7	1
250	-13	-13	-7	1
500	-6	-9	-5	1
1000	7	-1	1	1
5000	112	74	32	5

If the shadow price of illegally dumped waste is zero the results are (of course) the same as for the situation that no waste is illegally dumped (see table 7). When the shadow price of illegal dumping raises the unit-based systems become less attractive compared to the flat rate system. When the shadow price is 180 euro per ton (the social costs for one ton solid waste at the curbside), the weight-based system is socially still preferred, although the difference with the bag system is almost zero. It seems reasonable to assume that the social valuation of illegal dumping is above the level of 180 euro per ton. However, the shadow price of illegal dumping should be raised almost four times for the flat rate to perform better than the weight-based system. Therefore, from a social point of view there seems room for further implementation of weight-based or bag-based pricing systems. If the shadow price of illegal dumping is approximately 750 euro, social costs are equal for both systems. In this case the bag and volume and frequency system still produce social benefits. However, when the shadow price is more than 1072 euro, which can be interpreted as extreme dislike of society for illegal dumping, the flat rate system is preferred above all other systems.

4. Conclusions

This paper provides an empirical analysis of the effects of unit-based pricing of household waste for the Netherlands. We find significant and sizeable effects for weight-based, bag-based and frequency-based pricing systems. For example, weight-based pricing shows to be effective in reducing solid waste (-49%) and compostable waste (-61%) and increasing recyclable waste (+21%). This is in line with our results by Linderhof et al. (2001) for Oostzaan. Moreover, bag-based pricing is also effective in reducing solid waste (-51%) and increasing recyclable waste (+21%). This is an interesting result, because administrative costs for bag-based pricing are much lower.

Moreover, we show that the political affiliation of a municipality is unimportant for the size of the price effect and that there is no evidence that surrounding municipalities without a pricing system in fact collect part of the waste produced in municipalities with a unit-based pricing system. Less evidence is available for the size of illegal dumping. Based on earlier estimates by Fullerton and Kinnaman (1996), we show that if the social valuation of illegal dumping is in line with the costs of collecting and treating solid waste the weight-based system (or bag system) is preferable.

From a social point of view there seems room for a further implementation of especially weight- and bag-based system. Both decrease the amount of solid waste with high environmental costs substantially and increase the amount of recyclable waste with large environmental benefits, which compensate the system costs. As the main disadvantage of these systems is the effect on illegal dumping, it seems worthwhile to investigate an effective monitoring and fining system and the conditions under which such a system works.

APPENDIX

Definition of variables

$Waste_{tot}$	Total collected waste per inhabitant
$Waste_{sol}$	Total collected solid waste per inhabitant
$Waste_{vfg}$	Total collected vegetable, fruit and garden waste per inhabitant
$Waste_{gpt}$	Total collected glass, paper and textile waste per inhabitant
$Diftar_{weight}$	Dummy if inhabitant pays per kilogram
$Diftar_{bag}$	Dummy if inhabitant pays per bag
$Diftar_{volfre}$	Dummy if inhabitant pays related to volume of waste bin and frequency of collection
$Diftar_{vol}$	Dummy if inhabitant pays related to volume of waste bin
$Diftar_{oth}$	Dummy if inhabitant pays related to some other quantity measure
Retire	Percentage of inhabitants older than 65
Fam size	Number of inhabitants per household
Foreigner	Number of non-western foreigners per inhabitant
City	Dummy for municipalities with more than 100,000 inhabitants
Village	Dummy for municipalities with less than 20,000 inhabitants
Density	Area of municipality in hectare per inhabitant
Own_{house}	Number of real estate houses sold per inhabitant
Own_{flat}	Number of real estate flats sold per inhabitant
Income	Percentage of inhabitants with middle income (more than 12.400, less than 21.400 euro)
$Impact_{weight}$	Variable measuring surrounding municipalities with weight-based pricing system
$Impact_{bag}$	Variable measuring surrounding municipalities with bag-based pricing system
$Impact_{volfre}$	Variable measuring surrounding municipalities with volume and frequency-based pricing system
$Impact_{vol}$	Variable measuring surrounding municipalities with volume-based pricing system
$Impact_{oth}$	Variable measuring surrounding municipalities with other-based pricing system

REFERENCES

Brisson, I., 1997, Assessing the Waste Hierarchy, a Social Cost-Benefit Analysis of Municipal Solid Waste Management in the European Union (AKF Forlaget, Copenhagen).

CE, 1999, Efficiënte prijzen voor het verkeer ("Efficient Transport Prices") (CE, Delft).

Dijkgraaf, E. and H.R.J. Vollebergh, 1998, Incineration or Dumping? A Social Cost Comparison of Waste Disposal Options, OCFEB Research Memorandum 9808 (OCFEB, Rotterdam).

Dijkgraaf, E., R.F.T. Aalbers and M. Varkevisser, 1999, Afvalmarkt in de branding ("Waste Market at Risk"), OCFEB Studies in Economic Policy, no. 2 (OCFEB, Rotterdam).

Dijkgraaf, E., R.F.T. Aalbers and M. Varkevisser, 2001, Afvalprijzen zonder grens. Een analyse van de Nederlandse afvalverbrandingsinstallaties in een Europese markt ("Waste Prices Without Borders. An Analysis of the Position of Dutch Waste Incineration Plants in a European Market"), OCFEB Studies in Economic Policy, no. 4 (OCFEB, Rotterdam).

Dijkgraaf, E., R.H.J.M. Gradus and B. Melenberg, forthcoming, The Institutional Choice of Refuse Collection: Determining Variables in the Netherlands, Empirical Economics.

EC, 2001, Waste Management Options and Climate Change (EC, Brussels).

Fullerton, D. and T.C. Kinnaman, 1996, Household Responses to Pricing Garbage by the Bag, American Economic Review 86(4), 971-984.

Hong, S., R.M. Adams and H.A. Love, 1993, An Economic Analysis of Household Recycling of Solid Waste: The Case of Portland, Oregon, Journal of Environmental Economics and Management 25(23), 136-146.

Hong, J., 1999, The Effect of Unit Pricing System Upon Household Solid Waste Management: The Korean Experience, Journal of Environmental Management 57, 1-10.

Jenkins, R.R., 1993, The Economics of Solid Waste Reduction: The Impact of User Fees (Edward Elgar, Aldershot).

Kinnaman, T.C. and D. Fullerton, 1997, Garbage and Recycling in Communities with Curbside Recycling and Unit-based Pricing, NBER Working Paper 6021 (NBER, Cambridge).

Kinnaman, T.C. and D. Fullerton, 1999, The Economics of Residential Solid Waste Management, NBER Working Paper 7326 (NBER, Cambridge).

Linderhof, V., P. Kooreman, M. Allers and D. Wiersma, 2001, Weight-based Pricing in the Collection of Household Waste: The Oostzaan Case, Resource and Energy Economics 23, 359-371.

Podolsky, M.J. and M. Speigel, 1998, Municipal Waste Disposal: Unit-pricing and Recycling Opportunities, Public Works Management and Policy 3(1), 27-39.

Reschovky, J.D. and S.E. Stone, 1994, Market Incentives to Encourage Household Waste Recycling: Paying for what you Throw Away, Journal of Policy Analysis and Management 13(1), 120-139.

VROM, 1997, Ervaringen met tariefdifferentiatie en huishoudelijk afval ("Experience with Differentiated Tariffs and Domestic Waste") (Ministry of Environmental Affairs, Den Haag).
Wertz, K.L., 1976, Economic Factors Influencing Households' Production of Refuse, Journal of Environmental Economics and Management 2, 263-272.
WS, 2000, Waste Strategy 2000 (Department of the Environment, Transport and the Regions, London).