Environmental activism and dynamics of unit-based pricing systems

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Abstract

It is well-known that unit-based pricing systems have a significant effect on the quantity of collected waste. Part of this effect may, however, result from a selection bias or environmental activism effect. Based on a pooled cross-section for the Netherlands for 1998-2005 we show that despite the correction for environmental activism the effect of the weight and bag unit-based pricing system on the quantity of waste is sizeable. Moreover, this environmental activism effect is decreasing over time, so that the most environmental friendly municipalities implement unit-based pricing systems at first. In addition, we show that the volume-effects of the different unit-based pricing systems are rather stable over time. Although we find some evidence for a learning effect, nearly no evidence is found for an awareness erosion effect. This means at least that the effect of unit-based pricing does not decrease over time, which is reassuring from an environmental point of view. Pricing waste helps.

JEL classification: H31; H71; Q38.

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1. Introduction

A growing number of Dutch communities has implemented unit-based pricing (or user fees) to pay for waste collection. Between 1997 and 2005 the share of municipalities that implemented unit-based pricing increased from 14% to 31%. Unit-based pricing systems are also used in some other countries. In the US 4,000 municipalities (i.e. 25%) require households to purchase a special can, bag, tag, or sticker for each unit of garbage presented for collection (Miranda and Byrum, 1999). In the Flemish region of Belgium many municipal authorities implemented unit-based pricing systems (Gellynck and Verhelst, 2007). While in other EU countries unit-based pricing is widespread (Austria, Finland, Germany, Italy and Luxembourg) or used in a minority of municipalities (Denmark, France, Ireland and Sweden), some countries do not use this system at all (Portugal and Spain) (Hogg, 2002). In the UK the system is even prohibited by law (see also Hogg, 2002). In addition, South-Korea has implemented a compulsory unit-based pricing system (OECD, 2006).

In the literature there has been an extensive empirical discussion about the effects of unit-based pricing systems after the contribution by Fullerton and Kinnaman (1996).[1] Recently, Kinnaman (2006) gives an overview of the empirical studies, which have appeared since then. He shows that the most refined systems are effective. For the bag and weight systems the price elasticities differ from -0.08 to -1.10 with an average of -0.45. Two streams of literature that estimate household reactions to the implementation of unit-based pricing systems can be distinguished. The first applies household survey data and the second uses cross-sectional analyses of municipalities. Survey data requires the cooperation of households. This method is difficult and expensive when data for a long time-period are required. Furthermore it can create potential self-selection problems as motivated households are more eager to cooperate. Cross-sectional analysis can rely on administrative data, which makes it easier and less expansive to apply. A drawback, however, is that but there can be large differences between municipalities as municipalities with high fees likely have inhabitants with different environmental attitudes than those with low fees (see also Isely and Lowen, 2007). However, if cross-section data are available for several years, it should be possible to correct for this selection bias or so-called environmental activism effect.

In this paper we correct for the environmental activism effect based on a Dutch municipal yearly dataset for 1998-2005. It will be shown that municipalities that introduce a unit-based pricing system already produce 6% less waste on average before its introduction. This means

[1] Also in theoretical papers the importance of unit-based unit pricing has been stressed (e.g. Calcott and Walls, 2005).

that the previous literature probably overestimates the effect of unit-based pricing as it takes environmental activism not into account. Moreover, we show that this environmental activism decreases over time. This result makes sense as we should expect that the most environmental friendly municipalities will introduce a fee sooner. However, it gives no indication for the opposite efficiency hypothesis suggesting that municipalities with high waste levels introduce unit-based pricing as the expected positive effect are larger for them (as a result of fewer options already applied).

We extend the literature also in two other directions. First, we explicitly distinguish between the different systems of unit-based pricing (weight-, bag-, frequency- and volume-based pricing). The results points out that the more refined unit-based pricing systems such as the bag- and weight-based systems perform far better than the frequency- or volume-based systems. This is line with our earlier contribution based on municipality level data for a smaller period (1998-2000) (Dijkgraaf and Gradus, 2004). Second, we are able to analyze the effects of different unit-based pricing systems over time. Interestingly, the yearly volume effects of unit-based pricing systems are rather stable over time. So, there is no indication for awareness erosion. For the opposite learning effect we also find hardly evidence, although some cases are present that show significant results. The overall conclusion is that unit-based pricing works.

The paper is organized as follows. In section 2 data and method are discussed. In section 3 estimation results are given. In section 4 the time-dependent unit-based system dummies are discussed. Finally, section 5 contains some conclusions.

2. Data and method

Our methodology is characterized by estimating an equation with on the left-hand side the quantity of residential waste collected and on the right-hand side dummies for municipalities with a unit-based pricing system and variables correcting for socio-economic differences between municipalities (see, for example, Kinnaman and Fullerton, 1997). As data are available for 1998–2005, we estimate a pooled cross section model using both the cross-section and the time-related variation.[2] For each residential waste stream we estimate:

[2] Ideally, we would use the time-related variation to estimate the effect on the basis of comparing waste quantities before and after the introduction of unit-based pricing. However, we do not have enough time-variation to use this technique which makes it necessary to compare results between municipalities with and without a unit-based pricing system. Note that this necessitates the test of the discussed effect of environmental activism.

$$Waste_{w,i,t} = \alpha_s UBP_s + \beta_1 EAC + \beta_t EAC_t + \gamma\, SE + c_0 + c_i + d_t + \varepsilon_{i,t} \quad (1)$$

where $Waste_{w,i,t}$ is the quantity of residential 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, EAC has the value 1 for all years for each municipality introducing unit-based pricing in one of the available years, EAC_t has the value 1 for all years for each municipality that introduces a unit-based pricing system in year t (with 1998 as benchmark), SE is a vector of socio-economic characteristics, c_0 is the general constant, c_i are time-invariant regional fixed effects (with one region as the benchmark),[3] d_t are time fixed effects (with 1998 as benchmark) and $\varepsilon_{i,t}$ is the normally distributed error term (where necessary corrected for cross-sectional heteroskedasticity).

We use the quantity of residential waste collected ($Waste_{w,i,t}$) at the municipal level (in kilograms per inhabitant) as the dependent variable. We are able to discriminate between different waste streams as we have data for compostable waste (such as vegetable, food and garden waste), recyclable waste (glass, paper and textiles) and unsorted waste. Dutch municipalities are obliged to collect two types of waste at the curbside: compostable waste and unsorted waste. Municipalities can choose whether they collect at the curbside or provide near-by drop-off centers for recyclable waste.[4] For municipalities without curbside collection for 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, many municipalities place collection units at shopping centers and at entrance roads of neighborhoods.

We analyze also total residential waste, the sum of the three waste streams. Waste quantities come from studies by the Dutch Waste Management Council (AOO) and are available for the period 1998 to 2005. 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. The response rate of the inquiry is on average 92%, differing between years from 90% in 1999 and 95% in 2001. Thus, our data-set comprises nearly all Dutch municipalities. The actual number of municipalities included differs for each dependent variable due to data availability.[5] The

[3] It is not possible to include a fixed effect for each municipality as the activism dummy is 1 for each municipality that introduces unit-based pricing. Therefore, we include a dummy for each province. Results for these fixed effects are available upon request.
[4] Both methods seems equally effective. For US-data it is shown that the marginal impact of expanding curbside collection on recycled quantities is small, because curbside programs cannibalize returns from drop-off centres (see Beatty et al. (2007)).
[5] As not for all municipalities data are available for all years, the number of observations is not exactly equal to

first four rows in Table 1 present summary and availability statistics for the independent variables.

Table 1. Descriptive statistics

	Mean	Max	Min	Std. Dev.	Obs.	Mun.
Waste total	429	1066	197	67	3132	487
Waste unsorted	221	914	68	58	3604	496
Waste compostable	112	301	1	42	3592	495
Waste recyclable	99	287	19	20	3149	488
EAC	0.32	1.00	0.00	0.47	3604	496
- 1998-1999	0.05	1.00	0.00	0.22	3604	496
- 2000-2001	0.07	1.00	0.00	0.25	3604	496
- 2002-2003	0.03	1.00	0.00	0.17	3604	496
- 2004-2005	0.03	1.00	0.00	0.17	3604	496
RETIRE	0.14	0.28	0.06	0.03	3604	496
FAMSIZE	2.52	3.70	1.08	0.21	3604	496
FOREIGNER	0.04	0.35	0.00	0.04	3604	496
CITY	0.05	1.00	0.00	0.23	3604	496
VILLAGE	0.52	1.00	0.00	0.50	3604	496
DENSITY	0.67	5.26	0.004	0.82	3604	496
INCOME	29.88	76.52	5.08	5.02	3604	496

Table 2. Unit-based pricing in 1997-2005

	UBP_WEIGHT	UBP_BAG UNS and COM	UBP_BAG Only UNS	UBP_FRE	UBP_VOL	Total
Level in 1997	12	6	20	13	27	78
New in:						
- 1998	2	0	0	5	0	7
- 1999	1	0	0	17	6	24
- 2000	4	0	3	9	2	18
- 2001	3	0	2	5	14	24
- 2002	5	1	1	9	2	18
- 2003	0	0	0	0	0	0
- 2004	2	1	1	6	6	16
- 2005	2	0	0	5	1	8
New: total	19	2	7	56	31	115

Dutch municipalities are free to choose the financing mechanism for waste collection of unsorted and compostable waste, while they are obliged to supply a free collection system for paper, glass and textiles. Most municipalities finance waste collection by a flat rate. However, in order to promote waste prevention and recycling, an increasing number of municipalities have introduced a unit-based pricing system. Starting from 78 in 1997, 115 Dutch municipalities introduced a unit-based pricing system between 1997 and 2005. Dutch municipalities have introduced different types of unit-based pricing (UBP) systems. Four different UBP systems can be distinguished: volume-, frequency-, bag- and weight-based.

the number of years multiplied by the number of cross-sections.

Table 2 gives an overview of the pricing systems already used in 1997 and the pricing systems introduced by Dutch municipalities in the period 1998–2005 (see variables UBP_WEIGHT, UBP_BAG, UBP_FRE and UBP_VOL in Table 2).[6]

The volume-based program allows households to choose between different volumes of the collection can and in 1997 27 municipalities in the Netherlands used this rather crude UBP system. Between 1997 and 2005, 31 Dutch municipalities introduced such a system. A more refined marginal price results from a frequency-based system, the household pays now for the number of times the can is presented at the curbside. This type of system was used by only 13 municipalities in 1997 and 56 municipalities introduced such a system between 1997 and 2005. With the bag-based system households buy a bag with specific marks. 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 and the bag system allows households to change volume each week. Although 26 Dutch municipalities used a bag-based system in 1997, the number of introductions between 1997 and 2005 was very small. This relative low number is due to Dutch legislation limiting the number of bags carried by employees and the incentive for households to put as much waste as possible in each bag which makes them difficult to handle. Contrary to the other systems, the bag-based system is generally used for unsorted waste only (see variable UBP_BAG UNS). However, in 1997 six municipalities use this system also for compostable waste (see variable UBP_BAG UNS and COM). Maximum price incentives result 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. A disadvantage of this system is high administrative costs and therefore only 12 Dutch municipalities had such a system in 1997, while 19 municipalities introduced this system between 1997 and 2005.[7]

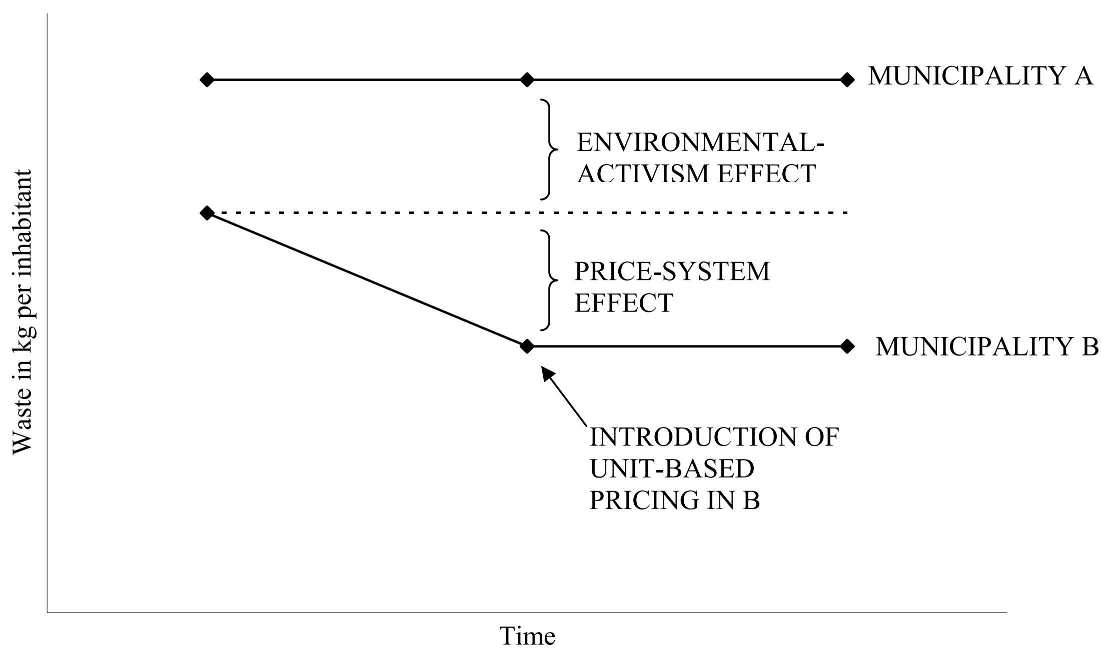
Previous studies show that unit-based pricing systems have a significant effect on the quantity of collected waste (see for an overview Kinnaman (2006)). Part of this effect may, however, result from a higher level of environmental activism. Figure 1 illustrates this point. Assume that citizens in municipality 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. To estimate the effects of unit-based pricing systems one normally compares the waste

[6] Note that Table 2 describes unit-based pricing for all municipalities, while Table 1 summarizes the data used in the estimations.

[7] In VROM (1997), there was an evaluation of the administrative costs of the weight-, bag- and frequency-based pricing systems in 12 Dutch municipalities. According to this study, yearly average administrative costs in 2005 prices are higher for the weight-based pricing system ($ 26 per household) than for the other systems ($ 12 euro for the bag-based system, $ 17 for the frequency-based system).

quantities of both municipalities, resulting in an estimate that is the sum of the environmental-activism effect and the price-system effect. 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. 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 minus the difference in the first period. Therefore, the estimated effects of a unit-pricing system might already include the effect of environmental activism. We test this by including a dummy variable (EAC) that has the value 1 in all years for each municipality that introduces a unit-based pricing system in our sample period and the value 0 otherwise. 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.

Figure 1. Influence of environmental activism on quantity of waste



In addition, we are interested in the environmental activism effect over time as well. Therefore, we also include a time-variant environmental activism dummy (EAC_t), which has the value 1 in all years for each municipality that introduces a unit-based pricing system in a specific year. Due to the fact that the number of introductions can be small in a specific year, we distinguish between four two-year periods (i.e. 98-99, 00-01, 02-03 and 04-05) to capture this time-effect. The dummy EAC in Table 1 makes clear that 32% of municipalities has a unit-based pricing system in one or more years.[8] In the period 1998-1999 5% of the municipalities introduced unit-based pricing. This rate increases to 7% in the next period and decreases to 3% in the last two periods. It should be noted that efficiency suggest an opposite hypothesis compared with the environmental activism effect. Efficiency gives municipalities that have underinvested in options to reduce the waste volume a higher incentive to adopt unit-based pricing. These municipalities have a higher expected impact on waste volumes as not many waste reducing options are already applied. If statistical evidence is found for the environmental activism effect, the efficiency hypothesis is not supported.

Another important issue for selection bias is that the estimation results can reflect the introduction of new recycling programs at the same time as UBP is introduced (see also Kinnaman for the USA (2005)). However, for the Netherlands we do not have indications for such an effect. The Dutch law requires that all municipalities have recycling programs for the separate collection of paper, glass, textiles and compostable waste. Moreover, recycling methods in Dutch municipalities are very comparable for most waste streams. For glass and textiles 99% of the municipalities use a drop-off system, while nearly all municipalities use a curbside program for compostable waste (in almost all cases with a biweekly frequency). For paper, however, large differences are visible between municipalities. Nevertheless, the share of recycling programs is very much comparable between municipalities with and without UBP.[9] Therefore, we can conclude that there is no indication that estimation results are biased as a result of concurrent introduction of new recycling methods.

To correct for differences between municipalities, we include the following socioeconomic characteristics:[10] the number of inhabitants of a municipality per area (and its square) (DENSITY), the average family size (FAMSIZE), the number of non-western foreigners per inhabitant (FOREIGNER), the percentage of total inhabitants earning a median income (INCOME), a dummy for small municipalities (VILLAGE), a dummy for large

[8] Note that this is not equal to the sum of the unit-based pricing dummies as the EAC dummy's get the value 1 also in years before the introduction of unit-based pricing.
[9] For 1998, data are available, which shows that 52% of the municipalities used a curbside program, 12% of the municipalities a drop-off program and 36% a combination of both. However, there is no or a very low correlation between these methods and UBP. For curbside the correlation coefficient is 0.03 , for the drop-off system it is 0.01 and for a combination of both it is -0.01.
[10] These socio-economic characteristics are based on the available literature (e.g. Kinnaman and Fullerton 1997). Most characteristics speak for themselves. Home ownership and surface are an important explanation for differences in residential waste and is measured by DENSITY, VILLAGE AND CITY. FOREIGNER is a proxy for the level of unemployment.

municipalities (CITY)[11] and the percentage of inhabitants older than 65 (RETIRE). Data for the socio-economic characteristics come from the CBS. See Table 1 for descriptive statistics.

3. Unit-based pricing and environmental activism

Table 3 presents the estimation results.[12] Pricing waste on the basis of weight has a highly negative and significant effect on total waste of 32%.[13] This effect differs for the underlying waste streams. Compostable waste diminishes by 59%. 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 39%. 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 of glass, paper and textiles (up 12%). 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.

Introducing a bag-based pricing system also reduces total waste. In municipalities that use the bag-based system for both unsorted and compostable waste, total waste diminishes by 31%. For municipalities that use the bag-based system for unsorted waste only, compostable waste is now collected by using a free collection can, the reduction is not more than 10%. While the effects on unsorted waste are more or less comparable for the two systems (−41% and −52%), the effect on the supply of compostable waste differs greatly. In municipalities with non-priced compostable waste collection, compostable waste increases (by 44%), while in the other municipalities, this waste decreases (by 59%). Interestingly, the effect on recyclable waste is also somewhat larger for municipalities that use the bag-based system for unsorted and compostable waste. Summarizing, 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 total waste by 20%, due to a reduction in both unsorted waste (23%) and compostable waste (44%). The effect on recyclable waste (+5%) is also less compared with the weight and bag-based system.

[11] Small municipalities are defined as municipalities with less than 20,000 inhabitants (53% of all observations). large municipalities are defined as municipalities with more than 100,000 inhabitants (5% of all observations).
[12] The *F*-statistics show that the equations are significant and the relatively high (adjusted) R^2s indicate that the explained variation is not small.
[13] As the estimations are in logs the effect of the dummies are calculated as e^x-1 with x the coefficients as presented in Table 2.

The effects of introducing a system based only on the volume of the collection can are still smaller and in all cases insignificant. This result is not surprising since the volume-based system is less refined than the other systems.

Table 3. Estimation results with time dependent EAC

	Waste total[a]		Waste unsorted[a]		Waste compostable[a]		Waste recyclable[a]	
UBP_WEIGHT	-0.39	***	-0.50	***	-0.88	***	0.11	***
UBP_BAG UNS and COM	-0.37	***	-0.53	***	-0.78	***	0.13	***
UBP_BAG Only UNS	-0.10	***	-0.74	***	0.37	***	0.14	***
UBP_FRE	-0.22	***	-0.27	***	-0.58	***	0.05	***
UBP_VOL	-0.01		-0.03		0.02		-0.01	
RETIRE [a]	0.09	***	0.03	*	0.23	***	-0.01	
FAMSIZE [a]	-0.04		-0.37	***	0.43	***	0.16	***
FOREIGNER [a]	-0.03	***	0.02	***	-0.13	***	-0.03	***
CITY	-0.04	***	0.02	***	-0.23	***	-0.16	***
VILLAGE	0.00		-0.03	***	0.05	***	0.03	***
DENSITY [a]	-0.01	***	0.04	***	-0.13	***	0.00	
DENSITY2[a]	0.01	***	0.03	***	-0.02	***	0.01	***
INCOME [a]	-0.03		-0.13	**	0.38	***	0.19	**
1999	0.02	***	0.03	***	-0.03	***	0.03	***
2000	0.04	***	0.07	***	-0.03	**	0.00	
2001	0.04	***	0.07	***	-0.05	***	0.01	*
2002	0.04	***	0.08	***	-0.06	***	-0.01	
2003	0.01	***	0.07	***	-0.15	***	-0.04	**
2004	0.04	***	0.09	***	-0.12	***	-0.04	
2005	0.03	***	0.09	***	-0.18	***	-0.04	
EAC	-0.06	***	-0.10	***	-0.06	***	0.05	***
- 2000-2001	0.03	***	0.05	***	0.05	**	0.00	
- 2002-2003	0.04	**	0.06	**	0.09	*	-0.03	**
- 2004-2005	0.07	***	0.09	***	0.01		0.01	
Constant	5.98	***	6.12	***	2.43	***	3.71	***
Number of observations	3,132		3,604		3,592		3,149	
F	192,49		299,51		139.44		48.23	
R^2	0.68		0.74		0.57		0.34	

Note: */**/*** means significance at 90/95/99%. Variables with a are estimated in logs.

As Table 3 shows, the environmental activism dummy is significant for total, unsorted and recyclable waste. The results indicate that municipalities with a high level of environmental activism have 6% less total waste. Especially for unsorted waste —the most environmentally unfriendly waste stream— the effects are large. Municipalities with a high level of environmental activism have 9% less unsorted waste and 6% less compostable waste. As recyclable waste in such ‘green’ municipalities is 6% 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. This means also that the efficiency hypothesis, municipalities with high waste levels have more incentives to introduce unit-based pricing, is not supported.

Although we find significant effects of environmental activism, the effects of the different unit-based pricing system on the quantities of the different waste streams are still sizeable. This means that studies not including environmental activism are overestimating the unit-based pricing effect, but activism does not dominate this effect. Unit-based pricing is effective after all.

For the total waste stream the time-dependent environmental activism dummy goes up from 0.03 in 2000/2001 to 0.07 in 2004/2005, meaning that the overall environmental activism effect ($EAC-EAC_t$) is decreasing over time. At the end of the period the effect of environmental activism is not different from zero anymore. This result makes sense as we should expect that the most environmental friendly municipalities will introduce a unit-based system at first. For unsorted waste the same pattern occurs and the time-dependent environmental activism dummy goes up from 0.05 in 2000/2001 to 0.09 in 2004/2005. The overall effect is insignificant again at the end of the period. For recyclable and compostable waste the environmental activism effect, however, is still significant at the end of the period. Although some corresponding effects are found between 2000 and 2003, we find for 2004/2005 an insignificant period dummy. Apparently, the effect of environmental activism persists much longer for compostable and recyclable waste streams.

Turning to the socio-economic characteristics, we find economies of scale (family size) for unsorted and no economies of scale for total waste. This corresponds to the results found in the literature. Diseconomies of scale are found for compostable and recyclable waste. A possible explanation for compostable waste 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. A sizeable effect is also found for recyclable waste. A reason behind this effect could be that in cities the costs of recycling are higher as transport costs are higher compared with villages. This can be true for two reasons. First, villages have less congestion and thus less travel time to drop-off cites. Second, villages have more activities of charity funds picking up paper at the curbside. Moreover, a larger area per inhabitant increases the waste stream. The coefficients on income for compostable and recyclable waste are significant and positive. As the effect on total waste is insignificant, the positive effects for compostable and recyclable waste are compensated by a decrease in unsorted waste.

Households with a higher income might sort their waste better. This is in accordance with one of the assumptions behind the Environmental Kuznets Curve that assumes that higher income stimulates awareness (Dijkgraaf and Vollebergh, 2005). Furthermore, the time-fixed effect is positive for total and unsorted waste and negative for compostable waste. Except for compostable waste there is no general acceleration in the quantity of waste.

4. The dynamic effects of unit-based pricing

Section 3 shows that unit-based pricing has a significant effect on the total amount of collected waste, with or without correction for environmental activism. Based on our dataset it is also possible to investigate how the effects of the different unit-based pricing systems develop over time. This is important as short-term and long-term effects might differ due to learning effects and awareness erosion. It is possible that the introduction of unit-based pricing make households aware of the costs of waste. However, if households get used to pricing waste and go back to their old behavior, the awareness effect of UBP might erode over time. In addition, learning effects can be present as well. If this is the case, households need time to learn how to change their behavior which will result in a negative effect of UBP on waste quantities that increases over time. The mechanisms together will shape the time pattern of unit-based pricing. From a theoretical point this pattern is undetermined. Therefore, we estimate the equation again, but now including information on the year of introduction. Now, for each waste stream (total waste, unsorted waste, recyclable waste and compostable waste), we estimate:

$$Waste_{w,i,t} = \alpha_s UBP_s + \alpha_{st} \sum_{t=2}^{n} UBP_s Y_t + \beta_1 EAC + \beta_t EAC_t + \gamma\, SE + c_0 + c_i + d_t + \varepsilon_{i,t} \qquad (2)$$

where the dummy Y_2 has a value if 1 if the year of introduction of unit-based pricing system s is one year ago and so on.[14] So, coefficient α_s gives the general effect of introducing a UBP-system, coefficient α_{s2} presents the extra effect due to the second year, and so on. Table 4 presents the number of municipalities with a unit-based pricing system in the different experience categories. For most years we have around 100 observations.[15]

[14] As for nearly all Dutch municipalities the introduction of the UBP system will take place in January we use a yearly dummy.

[15] Nevertheless, if we separate between specific unit-based pricing systems the number of observations can be small. We combine observation for several years if the total number of observations is less than 10 for a specific unit-based pricing system.

For total waste only the bag-based system pricing both unsorted and compostable waste shows some evidence for a learning effect in the long term (see Table 5).[16,17] We find a significant coefficient (but only at 90%) for bag-based systems that are in use for more than 7 years. However, only a minority of municipalities that have a bag-based system use bags for unsorted and compostable waste (seven municipalities) and therefore this result should be interpreted with caution. For the frequency and volume based system we find only a significant effect for an intermediate period and not for the long term.

Table 4. Number of municipalities with unit-based pricing related to years of experience

	UBP_WEIGHT	UBP_BAG UNS and COM	UBP_BAG Only UNS	UBP_FRE	UBP_VOL	Total
Year 1	15	2	5	50	28	100
Year 2	15	2	4	51	23	95
Year 3	14	1	12	47	23	97
Year 4	17	1	12	46	26	102
Year 5	15	5	12	38	22	92
Year 6	13	5	10	36	12	76
Year 7	12	5	7	29	9	62
Year 8	11	5	8	13	9	46
Year > 8	21	20	17	24	29	111

For unsorted waste we also find a significant long term effect only for the bag-based system pricing both unsorted and compostable waste (the effect is now even significant at 99%). As the effect is positive this indicates that the effectiveness of unit-based pricing is deteriorating over time suggesting awareness erosion. For the weight-based system we find a positive effect (at a significance level of 90%) only for the second and third year.

For compostable waste we find significant long term effects for both bag systems. For municipalities with a bag-based system pricing unsorted waste only, the amount of compostable waste increases after the introduction of this system. Thus, people are learning to avoid the fee on unsorted waste by increasing their amount of compostable waste. A learning effect is also present for municipalities pricing both unsorted and compostable waste with the bag system. For the frequency system we find only some evidence for learning effects as the period dummies are significant at 10% for three intermediate years only. Interesting is the result for the volume system. Although we find an insignificant effect for the general unit-based pricing dummy, some evidence is present that the long term effect is significant (but only at 90%).

[16] Equations are estimated with the same variables as in Table 3. In Table 5 we only present the estimation results for the unit-based pricing system dummies. The results for the socio-economic variables and the environmental activism dummy are very similar to those presented in Table 3 and are available upon request.
[17] Note that the number of observations is somewhat lower as for a few municipalities the year of introduction could not be determined.

For recyclable waste, we find significant long term effects for both the weight and bag-based system pricing unsorted waste only.[18] For both systems the long term effect is significant and positive (but only at 90%). So, for recycling we find some evidence of a learning effect. For the frequency and volume-based system we only find significant results for some intermediate years.

Table 5. Estimation results with time dependent unit-based pricing dummies

	Waste total[a]		Waste unsorted[a]		Waste compostable[a]		Waste recyclable[a]	
UBP_WEIGHT	-0.43	***	-0.53	***	-0.92	***	0.05	
$-Y_2$	0.06		0.09	*	0.18		0.06	
$-Y_3$	0.06		0.11	*	0.07		0.06	
$-Y_4$	0.00		0.01		-0.05		0.05	
$-Y_5$	0.03		0.01		0.03		0.06	
$-Y_6$	0.00		-0.03		-0.06		0.06	
$-Y_7$	0.04		0.01		0.05		0.07	
$-Y_8$	0.06		0.07		0.07		0.08	
$-Y_{>8}$	0.02		-0.04		0.01		0.10	*
UBP_BAG UNS and COM	-0.32	***	-0.59	***	-0.60	***	0.24	***
$-Y_{7/8}$	-0.06	*	0.03		-0.21		-0.09	***
$-Y_{>8}$	-0.08	*	0.09	***	-0.32	*	-0.18	***
UBP_BAG Only UNS	-0.10	***	-0.72	***	0.26	***	0.11	***
$-Y_4$	0.03		0.04		0.10		0.03	
$-Y_5$	0.04		0.02		0.12	*	0.05	
$-Y_{6/7}$	-0.01		-0.06		0.12	*	0.07	
$-Y_{>7}$	0.01		-0.06		0.18	***	0.10	*
UBP_FRE	-0.19	***	-0.22	***	-0.46	***	0.02	
$-Y_2$	-0.04		-0.07		-0.10		0.03	
$-Y_3$	-0.03		-0.03		-0.12		0.03	
$-Y_4$	-0.03		-0.04		-0.14		0.06	
$-Y_5$	-0.05		-0.06		-0.20	*	0.06	*
$-Y_6$	-0.06		-0.05		-0.22	*	0.00	
$-Y_7$	-0.08	*	-0.09		-0.25	*	0.06	
$-Y_8$	-0.08		-0.12		-0.14		-0.01	
$-Y_{>8}$	-0.07		-0.11		-0.10		0.04	
UBP_VOL	-0.01		-0.03		0.03		0.02	
$-Y_2$	0.01		0.01		-0.03		0.01	
$-Y_3$	0.01		0.01		-0.05		-0.05	
$-Y_4$	0.03		0.03		-0.02		-0.03	*
$-Y_5$	0.00		0.02		-0.08		-0.08	***
$-Y_{6/7}$	-0.06	*	-0.01		-0.17	***	-0.03	
$-Y_{>7}$	-0.05		0.00		-0.21	*	-0.03	
Number of observations	3,089		3,549		3,538		3,106	
F	108.64		161.35		78.92		26.88	
R^2	0.69		0.74		0.58		0.34	

Note: */**/*** means significance at 90/95/99%. Variables with a are estimated in logs.

[18] For the bag-based system pricing both unsorted and compostable waste the effect is opposite. Notice that this effect is probably due to the very small number of municipalities with such a system.

As Table 5 shows, the time-dependent UBP dummies are insignificant in many cases. Although we find some evidence of time dependent effects, often pointing in the direction of learning effects (especially for recycling), this evidence is rather scarce. Effects are often only significant at 90%, while for most systems effects are not significant at all. This means that we can conclude that in general the first year effect dominates the effect of unit-based pricing. Apparently, neither learning effects nor awareness erosion play a dominant role.

5. Conclusions

Based on a pooled cross section model for the Netherlands for 1998-2005, we show that unit-based pricing systems for waste treatment have a significant effect on the quantity of collected waste. Contrary to the literature we correct for the effect of environmental activism. We show that despite this correction for environmental activism the effect of the weight and bag unit-based pricing system on the quantity of total waste is large with 28-35%. Moreover, the environmental activism effect is decreasing over time, so that the most environmental friendly municipalities implement unit-based pricing systems sooner. This rejects the hypothesis that efficiency would stimulate municipalities with high waste levels to introduce unit-based pricing as they have lower marginal costs (as a result of less options already applied) to reduce garbage levels. In addition, we explore the time-variant effects of the different unit-based pricing systems as well. We showed that the volume effects of the different unit-based pricing systems are rather stable over time. Although we find some evidence for a learning effect, nearly no evidence is found for an awareness erosion effect. This means at least that the effect of unit-based pricing does not decrease over time, which is reassuring from an environmental point of view.

In future work there are many avenues to explore. First, as the use of dummy variables discards the actual price it is worthwhile to include such information in future research. In Dijkgraaf and Gradus (2004) we calculate such price elasticities using data for one year and show that Dutch elasticities are comparable with the elasticities found in the literature. However, it can be important to investigate such a question using price data for a longer time-period. Second, the introduction of unit-based pricing systems may have adverse effects as well. Citizens may dump their waste illegally. Not much evidence, however, is present for this effect in the Netherlands. Studying the effects of a weight-based system in Oostzaan, Linderhof et al. (2001) state that illegal dumping is virtually non-existent. The monitoring system in Oostzaan, with fines for illegal dumping, appears to be very effective in terms of deterrence. Moreover, a small municipality such as Oostzaan has a large degree of social control. No evidence is either found for effects of the introduction of unit-based pricing on neighboring municipalities that have no unit-based pricing system (Dijkgraaf and Gradus, 2004). Still, as illegal dumping is the most important factor against unit-based pricing, it is worthwhile to have more sound evidence whether this is a problem, what circumstances influence this problem and which solutions are effective. Third, a more rigorous treatment of the effects of recycling methods can be important as well. In this paper we show that for the Netherlands there are not many differences in recycling methods between municipalities, expect for paper. Based on data for 1998 we show that there is no correlation between the recycling programs and the use of unit-based pricing. However, it is worthwhile to test this point more rigorously in future research, if more data for paper recycling methods are available or with data for other countries. Fourth, we could investigate whether a truncation effect exists or not. In the paper we only investigate switches until 2005. However, it is possible that our dataset consists in fact of municipalities switching right after 2005 and municipalities that never want to switch. It is, of course, important to understand why municipalities switch. In future research such a truncation effect should be analyzed when more data are available.

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