Effective landfill taxation: A case study for the Netherlands

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Abstract

The landfilling tax is a well-accepted instrument to reduce landfilling of waste. However, there is hardly any research on evaluating the effectiveness of landfilling taxation. This study aims at investigating the effectiveness of a landfill tax in terms of market impacts and comparing the effectiveness with other waste policy instruments. Therefore, we performed two complementary analyses for the Netherlands. First, with econometric panel data estimation, we analysed *ex-post* the price effect of two typical combustible waste streams, namely household waste and waste from the service sector, over the period 1995–2003. The results show for the service sector that higher levels of landfill costs due to the increase in the landfill tax result in lower levels waste supply, less waste landfilled and more waste incinerated. For household waste, no significant effect is found due to the flat-fee pricing system most municipalities employ for waste collection. Secondly, we developed a general equilibrium model for the Dutch economy to assess *ex-ante* the landfill tax under different circumstances, such as market conditions and alternative waste policy instruments. The results show that a higher landfill tax results in lower amount of waste to be landfilled at the costs of a small loss of welfare. Municipalities will incinerate more waste, the service sectors recycles more waste. If export of combustible waste is allowed, then the service sector will also increase the amount of waste incinerated and consequently will slightly decrease their recycling efforts. Both analyses suggest that the present landfill tax rate of almost € 85 per tonne in the Netherlands is an effective measure to turn waste suppliers to alternatives. As long as the Dutch government prefers to base their waste policy on the waste hierarchy (i.e. waste incineration is preferred over landfilling), maintaining a high landfill tax on combustible waste is an effective option.

Keywords: landfill tax; combustible waste; general equilibrium models; panel data

JEL classification: C23; D58; Q20; Q28

1 INTRODUCTION

The European Commission envisages an important role for the use of economic instruments, such as landfill taxes, in developing a thematic strategy on the prevention and recycling of waste. A number of EU Member States already apply landfill taxation to reduce the amount of waste landfilled and to stimulate alternative disposal options such as recycling and re-use. Among the EU Member States, however, there is no consensus on the effectiveness of landfill taxation. Only a limited number of countries apply landfill taxation, while others prefer other instruments like a landfill ban.

The Netherlands is one of the EU Member States applying a landfill tax. It was introduced in 1996 and was primarily aimed at bridging the gap between the costs of landfilling and incineration. In fact, there are two landfill tax rates, a high rate for combustible and recyclable waste and a low rate for non-combustible waste. As such, the choice for this instrument and the rates that are applied in The Netherlands are mainly based on political and administrative considerations and decisions.

Scientific research on the effectiveness of landfill taxes is still scarce. An exploration at European level of the landfill tax would definitely benefit from more research into market conditions for an effective landfill tax. The present study is a first attempt to do so for the Netherlands. The focus is on combustible waste streams, such as household waste and comparable waste from the service sector (offices, shops etc.), as these are the waste streams to which EU policy pays a lot of attention and on which a lot of information is available.

This study aims at investigating the effectiveness of the landfill tax as a waste policy instrument in terms of market impacts. In particular, we will assess the (market) conditions at which a landfill tax will be effective. To address the effectiveness of landfill taxation, we will two perform complementary analyses for the Netherlands: an *ex-post* econometric analysis and an *ex-ante* analysis using an applied general equilibrium model.

Firstly, with an econometric panel data analysis, we determine the price effect of household waste and waste from the service sector in the Netherlands. The analysis includes the price effects of the total amount of waste supplied, the recycling rate, and the amount of waste landfilled and incinerated. Due to data availability, household data are analyzed at province level for the period 1995-2003, and service sector data at sub-sector level for the period 1995-2002.

In the analysis we will give specific attention to flat fee pricing for waste collection. Literature shows that because in the flat fee pricing system there is no direct link between the price of waste collection and the amount of waste generated, households will have no price incentive to separate waste. Therefore, if a unit-based pricing system is introduced households will start to recycle and separate more rest waste, see for example Jenkins (1993), Hong *et al.* (1993), Miranda *et al.* (1994), Morris and Holthausen (1994), Sterner and Bartelings (1999), Kinnaman and Fullerton (2000), and Calcott and Walls (2002).

Secondly, we will develop a static applied general equilibrium model for the economy of the Netherlands including households, service sector and a waste sector. With the model we will determine the impacts of different levels of the landfill tax on the total amount supplied and on treatment options. Moreover, we will be able to simulate the impacts of market developments, such as opening the national borders for import and/or export of combustible waste.

This paper is structured as follows. In section 2, we present the results of the econometric panel data analysis. In section 3, we present the results of the general equilibrium model. Section 4 concludes.

2 EX POST ASSESSMENT OF THE LANDFILL TAX IN THE NETHERLANDS

2.1 Introduction

Table 2-1 shows the amounts of waste per waste disposal option in the Netherlands in the period 1995-2003. Waste production continues to rise until the year 2000. However, this increase in waste is mostly recycled. Roughly 70-80% of the total amount of waste in the Netherlands is recycled. Here, recycling is used in a broad fashion, because it includes reuse of products, 'pure' recycling of waste and composting of organic waste. The total amount of landfilled waste more than halved in the period 1995-2003. In 1995, 8.2 Mton waste was landfilled, while in 2003 the amount of landfilled waste declined to 2.8 Mton.

One of the reasons why the share of waste landfilled dropped in the period considered is the implementation of landfill taxation and the steep increases in the landfill tax rates as shown in *Table 2-1*.

The Dutch waste sector has been affected by a number of regulations derived from international, national and regional environmental and waste policies. All these rules might have had a profound effect on the waste market (i.e. supply and disposal of waste) according to Dijkgraaf (2004). In 1995 a landfill tax and a landfill ban on combustible and recyclable waste was introduced simultaneously in the Netherlands although exceptions on the ban were allowed under certain circumstances. Until 2000, for instance, there was a ban on the trade of combustible (and non-combustible) waste between provinces in the Netherlands. Prior to the introduction of landfill taxation, the EU Waste Shipment Regulation was implemented to harmonise the trading of particular types of waste within the EU. Trading of waste was limited to recyclable waste. Also, Dutch municipalities are obliged to collect organic waste separately since 1994. Finally, in 2000 the source separation responsibility for producers was implemented for waste paper amongst others.

Table 2-1 Amount of waste per disposal option[a] and landfill tax rate[b] in the Netherlands in the period 1995-2005.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Disposal option	*Mtonne*										
Total	52.8	54.0	57.3	59.8	61.3	63.3	62.9	62.5	61.6		
Recycling	38.4	40.2	43.3	46.1	47.5	50.9	50.5	49.8	49.9		
Incineration	4.7	5.6	6.7	6.8	7.1	7.1	7.5	8.2	8.2		
Landfilling	8.2	6.7	5.8	5.5	5.5	4.8	4.8	3.9	2.8		
Discharge	1.4	1.5	1.5	1.4	1.2	0.4	0.1	0.6	0.7		
Type of waste	*€ per tonne*										
Combustible waste	13.25	13.25	13.25	29.13	29.75	64.28	65.44	78.81	81.65	83.61	84.78
Non-combustible waste	13.25	13.25	13.25	13.25	13.53	12.38	12.61	13.00	16.47	13.79	13.98

[a] Source: Waste Management Council in the Netherlands (AOO).

[b] Source: Dutch Environmental taxes act (art. 18).

In the ex-post assessment we try to identify the impact of the landfill tax on different kinds of developments in the waste (disposal) sector, such as waste supply and disposal choice options. In fact, the landfill tax is an additional cost component of landfilling waste, and the focus of the ex-post assessment is on the costs comparison of disposal options.

2.2 Determinants of waste supply and disposal options

To analyse the determinants of waste supply and disposal options, we composed two separate data sets for household waste and waste from the service sector based on data from AOO (2000, 2003a, 2003b, 2003c, 2003d, 2004a, and 2004b). The household data are collected at province level, and the service sector data at sub-sector level. The descriptive statistics of both datasets are presented in *Table A–1* and *Table A–2* in Appendix A. We apply panel data regression techniques, such as Fixed Effects (FE) estimation or Random Effects (RE) estimation, so that we can take into account heterogeneous (un)observed effects. As a consequence, determinants that are constant over time for regions (surface of regions for instance) or sectors (location of firms, for instance) cannot be taken into account.

The regression model looks as follows: total waste supply is regressed on economic growth, population growth and the relative price of incineration and landfilling.

$$Y_{i,t} = \alpha_{i,t} + \beta^X X_{i,t} + \beta^W W_{i,t} + \beta^P P_{i,t} + \varepsilon_{i,t}, \quad (2.1)$$

Where $Y_{i,t}$ is total waste supply at time t for sector/region i, $X_{i,t}$ includes demographic and economic determinants, such as Gross Domestic Product (GDP), population growth and other, $W_{i,t}$ includes indicators of other policy measures such as the (rest) capacity of waste disposal options, and $P_{i,t}$ is the (relative) price of waste disposal option at time t for sector/region i.

The landfilling tax can have a profound impact on the amount of waste recycled and the amount of waste incinerated. These impacts will be analyzed separately. This analysis is divided into two phases. Firstly, we start with the analysis of the 'choice' between recycling and waste disposal (the total of incineration and landfilling). The share of recycling is regressed on a number of determinants such as the price level of waste disposal options. In this way, we identify the impact of waste disposal prices on the share of recycling in total waste supply:

$$S_{i,t} = \alpha_{i,t} + \gamma^X X_{i,t} + \gamma^W W_{i,t} + \gamma^P P_{i,t} + \varepsilon_{i,t}, \qquad (2.2)$$

where $S_{i,t}$ is the share of recycling in the total waste supply at time t for sector/region i. This analysis is explored for both sectors (households and the service sector). The set of explanatory variables differs between both sectors. Secondly, we model the choice between incineration and landfilling in order to analyse the impact of the landfill tax (and landfilling costs) on the waste disposal choice:

$$D_{i,t} = \alpha_{i,t} + \delta^X X_{i,t} + \delta^W W_{i,t} + \delta^P P_{i,t} + \varepsilon_{i,t}, \qquad (2.3)$$

where $D_{i,t}$ is the total amount of waste supplied going to a specific disposal option (incineration or landfilling) at time t for sector/region i. The set $W_{i,t}$ in this case consists of indicators for policy measures such as the rest capacity of waste disposal options, the landfill ban and the opening of province borders for waste transport (in fact, the regulations of cross-border transportations were relaxed). In the case of the latter two, there are no quantity indicators for these policy measures. We therefore use dummy variable indicators for periods in which particular policy measures were present. Note however that we do not have the intention to estimate the impacts of all policy measures, but we try to obtain unbiased estimates for the other characteristics we can quantify in the analyses.

2.3 Results

Household sector

Table 2-2 presents the estimation results of household waste generation and disposal options. All equations (2.1), (2.2) and (2.3) are estimated with a Fixed Effects (FE) regression, which takes into account the possible (unobservable) heterogeneity between provinces. For convenience, we ignore the fixed effects themselves, and focus on the other determinants.

The determinants of household waste generation per capita are analyzed with Eq. (2.1). The waste disposal charge has no effect on waste generation, while provinces with higher shares of municipalities with unit-based pricing regimes tend to generate less waste per capita. Furthermore, the results show a significantly positive trend in the per capita household waste generation. Also, higher levels of GDP per capita lead to higher total amounts of household waste per capita. Finally, the number of single person households has a downward effect on household waste per capita.

To explain the share of recycling as in Eq. (2.2), we include the level of disposal costs explicitly, because we are analyzing the disposal option recycling versus incineration and landfilling. The disposal costs (costs of incineration and landfilling) are simply defined as the average of those two costs. Furthermore, we constructed disposal capacity, which is the total capacity of incineration and landfilling[1].

The second column of *Table 2-2* shows that the share of recycling in household waste increases with the level of per capita GDP, and there are some autonomous changes throughout the period. The share of recycling was higher in the 1995 and in the period 1996-1997 if we correct for the other determinants. Note that this does not mean that the total amount of recycled waste declined, which is only the case if the total level of household waste increased at a lower pace than the reduction in the recycling share. The third and fourth columns show the explanation of the amount of landfilled and incinerated household waste respectively according to the regression in Eq. (2.3). In these analyses, we include the relative price of landfilling over incineration.

GDP per capita has a positive effect on the total amount of landfilled household waste, and in 1995 the amount of landfilled household waste was significantly higher. Provinces with a higher share of municipalities with a unit-based pricing regime have a significant lower level of waste landfilling. The relative price of landfill costs has no significant effect.

From the incineration analysis (Eq 2.3b), we observe a significant positive effect of waste incineration by provinces with a higher share of municipalities with a unit-based pricing regime. Moreover, the availability of incineration capacity encourages waste incineration as well. This indicates that if there is sufficient incineration capacity available, municipalities will incinerate household waste instead of dumping it in landfills. Municipalities have a preference for incineration over landfilling because of the ban on landfilling household waste and the existence of long-term supply contracts between municipalities and waste incineration plants.

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[1] Since landfilling capacity is measured in volume, we use the weight per volume of 1,250 kg per cubic metre.

Table 2-2 Estimation results of household waste supplied per capita, share of recycable waste, household waste landfilled and incinerated per capita.

	Waste supplied (in 1000 kg)	Share of recycled waste	Waste landfilled (in 1000 kg).	Waste incinerated (in 1000 kg)
Variable description	Eq. (2.1)	Eq. (2.2)	Eq. (2.3a)	Eq. (2.3b)
Intercept	2.974	1.507	0.429	0.443
	(6.058)	(0.855)	(0.584)	(0.496)
GDP per capita	0.014**	0.015	0.018*	-0.003
	(0.003)	(0.011)	(0.007)	(0.007)
Share of municipalities	-0.087**	-0.008	-0.148*	0.164**
with unit-based pricing	(0.027)	(0.087)	(0.061)	(0.058)
Waste disposal charge	0.168			
(in € 1000)	(0.257)			
Price level of disposal costs		-2.393		
(in €)		(1.829)		
Relative price of landfilling			-0.045	0.018
over incineration			(0.108)	(0.105)
Share of single persons	1.774**	-4.007	-2.352	-0.936
	(0.894)	(2.809)	(1.860)	(1.605)
Landfill capacity			1.701	
			(1.142)	
Incineration rest capacity				0.015**
				(0.004)
Total disposal capacity		0.001		
		(0.001)		
Trend	-0.002			
	(0.003)			
1995		0.144**	0.113**	-0.027
		(0.040)	(0.038)	(0.038)
Period 1996-1997		0.125**	0.019	0.051*
		(0.030)	(0.204)	(0.020)
Period 1995-1998	-0.029**			
	(0.010)			
R^2 within	0.69	0.69	0.64	0.37
Number of regressors (k)	20	20	20	20
$F_{(k-1,NT-k)}$ with N=12 an T=9	33.67**	28.14**	22.26**	7.49**
$F_{(N-1,NT-k)}$ -test on fixed effects	28.56**	50.18**	15.17**	27.27**

** at 1% significance level, * at 5% significance level, and # at 10% significance level

The results of *Table 2-2* indicate that waste disposal charges did not affect the generation of household waste, and the costs of disposal options did not affect the amount of waste recycled, landfilled or incinerated. Basically, there is no effect, because changes in disposal costs are not internalized in the waste disposal charges. Therefore there is no empirical evidence that the landfilling tax had a significant impact on either the amount of municipal solid waste recycled or incinerated. It has also proven impossible to separate the effects of the landfill ban and the landfill tax implemented in the same year.

Service sector

The dataset for the waste supplied by the service sector is smaller than the household dataset. In contrast with the household waste data, we distinguish 5 subsectors within the service sector instead of spatial division, namely Retail and wholesale market (including repair industry), Hotel and catering industry, Transportation and communication, Financial services and insurance industry, and Other services (public management, health care, education and cultural services).[2]

Table 2-3 presents the estimation results of the service sector. The waste generation is estimated with Ordinary Least Squares (OLS), while for the other indicators we use the Random Effects (RE) panel data estimation. Sector-specific features are now included as a stochastic term instead of a dummy variable as in the Fixed Effects estimation. Again, we are not specifically interested in sector-specific effects but we are interested in unbiased estimates of the other determinants.

The waste generation equation, as in Eq. (2.1), shows that except for the sector dummies the employment per firm is the only significant determinant. Higher levels of employment imply higher levels of waste generation per firm. In the estimation of the recycling share of the waste sector according to Eq. (2.2), the level of the disposal costs (average of incineration costs and landfilling costs) has a significant positive impact on the share of recycling. Higher levels of disposal costs imply a higher share of recycling in the service sector.

From the estimations of the amount of landfilled and incinerated waste (Eq. 2.3), we observe that the relative price of landfill costs over incineration costs has a negative effect on the amount of waste landfilled, and a positive effect on the amount of waste incinerated. Higher levels of landfill tax will raise the relative price of landfill costs over incineration prices, and as a consequence, the service sector will use the incineration option more and the landfill option less.

2.4 Conclusions

The assessment of impacts of the landfill tax has resulted in different results for different sectors, because many aspects play a role. If the disposal costs are reflected in the costs charged to the waste suppliers, as is the case in the service sector, the landfill tax turns out to be an effective instrument. Higher levels of the landfill tax will imply lower levels of waste landfilled and higher levels of waste incinerated or recycled. If changes in disposal costs are not incorporated in the charges to the waste generators (as is the case of households), the landfill tax seems to be ineffective, especially if there is a landfill ban imposed as well. In that case, higher landfill taxes are not or delayed internalised in waste disposal charges. The intro-

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[2] Although AOO (2004) distinguishes 7 subsectors for the service sector, we will use a division of 5 subsectors due to lack of economic data. Note that in the ex-ante assessment in the next section 7 subsectors will be distinguished.

duction of unit-based pricing for household waste collection might provide the correct incentive in which higher landfill taxes are internalised.

Table 2-3 Results on the regressions of service sector waste per firm, share of recycled waste from the service sector, landfilled waste per firm, and incinerated waste per firm

	Waste supplied in 1000 kg	Share of recycled waste	Landfilled waste in 1000 kg	Incinerated waste in 1000 kg
Intercept	0.003	0.088	0.006**	0.002*
	(0.002)	(0.062)	(0.001)	(0.001)
Value added per firm (x 1000)		-0.072	-0.026*	-0.016*
		(0.229)	(0.010)	(0.008)
Employment per firm	0.931*	0.414	-0.032	-0.020
	(0.355)	(1.309)	(0.039)	(0.030)
Price level of disposal costs	0.004	3.373**		
	(0.016)	(0.613)		
Relative price of landfilling over incineration (x1000)			-2.191**	1.045*
			(0.492)	(0.481)
Disposal capacity per firm		-0.003		
		(0.007)		
Incineration capacity per firm				0.003
				(0.002)
Landfill capacity per firm			0.454*	
			(0.196)	
1995		-0.029	0.000	0.000
		(0.011)	(0.000)	(0.000)
Period 2000-2002		0.006	0.000	0.000
		(0.010)	(0.000)	(0.000)
Dummy for Hotel and catering services	0.002**			
	(0.001)			
Dummy for Transportation and communication services	-0.006*			
	(0.002)			
Dummy for Financial and insurance services	-0.006**			
	(0.001)			
Dummy for Other services	-0.010**			
	(0.003)			
Adjusted R^2	0.84			
R^2 within		0.74	0.64	0.28
Number of regressors (k)	7	7	7	7
$F_{(k-1, NT-k)}$ with N=5 and T=8	34.9			
Wald χ^2 (k-1)		94.1	72.5	23.2

** at 1% significance level, * at 5% significance level, and # at 10% significance level

3 EX-ANTE ANALYSIS

3.1 Introduction

Since the landfill tax is just one of the cost components of the total costs of landfilling, an econometric analysis on historical data such as in the previous section will not suffice for measuring the effectiveness of the landfill tax itself. Moreover, the presence of policy measures, such as flat fee pricing and landfill bans, complicates the estimation as well. Therefore, we also apply an ex-ante analysis to assess the effects of the landfill tax without the effect of these policies. We use an applied general equilibrium model simulating the Dutch economy.

In a simplified economy, two types of actors are distinguished: households and firms. Households consume goods and supply capital and labour; firms produce goods with the use of capital, labour and intermediate goods. The hypothetical economy is shown in *Figure 3-1*.

Consumption of services by private households leads to the generation of municipal solid waste. Waste must be either recycled or collected by the municipality. We differentiate two types of municipalities in this model. One municipality charges a flat fee for waste collection; the other municipality charges a unit-based price for waste collection. Comparing the results for the two different types of municipalities will show how the effectiveness of a landfill tax is influenced by the pricing mechanism for waste collection.

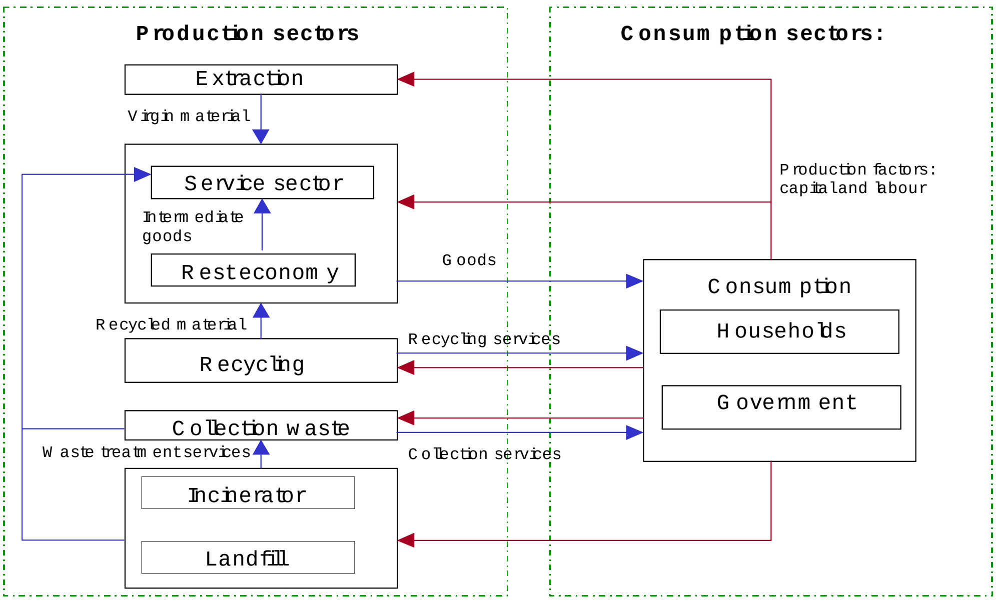

Figure 3-1 Representation of the economy

We assume that collected rest waste is not separated and recycled after collection, but instead is sent immediately to an incineration plant or landfill unit. We are primarily interested in the choice the consumer makes: the consumer can, for example, choose to separate organic waste, paper, or glass from rest waste. The consumers will have to incur costs in order to separate or recycle these materials. Recycling will, for example, cost the consumer both time and storage space. This is modelled as if the consumer buys 'recycling services'[3].

[3] In the rest of this paper we will use the term recycling for various activities the consumer can undertake to prevent rest waste: this includes waste seperation.

As indicated by the results of the econometric analysis in the previous section, the available incineration capacity has a profound impact on the substitution possibilities between incineration and landfilling. The available incineration capacity in the model will be limited. The total available incineration capacity will be insufficient to fully treat all municipal and production waste. Firms and municipalities, however, will have the option of exporting combustible waste. Thus the limitations of available capacity can be avoided and firms and municipalities will have the option to incinerate all their waste. Transporting costs and international prices of incineration will of course play a role in the decision whether or not to export waste.

3.2 Model structure

General equilibrium models can be built in different formats, such as the Computable General Equilibrium (CGE) format, the Negishi format, the full format, and the open economy format. Each of these formats has its strengths and weaknesses (see for more information Ginsburgh and Keyzer, 1997). In this paper we have chosen the Negishi format.[4]

In the Negishi format, total welfare is maximized subject to utility, balance, and production possibility constraints (Ginsburgh and Keyzer, 1997). The total welfare function is shown in equation 3.1. Total welfare (*TWF*) equals the sum of weighted utilities (u) over consumer i in country n[5]. Consumers derive utility from the consumption of goods provided by the service sector (x_i^g). The utility of each consumer is weighted by a factor α, the so-called Negishi weights[6].

$$TWF(\alpha) = \max \sum_i \sum_n \alpha_{i,n} u_{i,n}(x_{i,n}^g) + \xi^{ls} TL + \xi^{w} X^{w} \tag{3.1}$$

Countries can trade both incineration services and the consumption good 'rest economy'. The trade balance needs to be added to the model, which insures that the value of exported goods is equal to the value of imported goods:

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[4] Note that a format is just a way to build a general equilibrium model. Moreover, the choice of a format does not influence the optimal solution, only the way of finding it.

[5] In the model application presented in the next section we will distinguish only two consumers and the government, the model structure however is such that it is easy to distinguish many more consumers.

[6] These Negishi weights are determined in such a way that each consumer's budget constraint holds. This means that consumers cannot spend more money on goods and services than they receive on sales of primary inputs (capital and labor). The value of the Negishi-weights is exogenous to the model. Since the Negishi weight are only important for finding the optimal solution we will not report them.

$$\sum_j p_{j,n} z_{j,n} = 0 \qquad \textit{for each country } n \qquad (3.2)$$

Where z is the net trade and p is the price, note that if z is negative the country is a net importer of that good and if z is positive the country is a net exporter of that good.

For the Netherlands more detailed attention is given to both generation and treatment of waste. Part of the consumers living in the Netherlands pay a zero price for the collection of rest waste, namely those consumers that live in a municipality that charges a flat fee for the collection of rest waste. To introduce a zero price we assume that although the price of collection is equal to the marginal production costs, these consumers get a subsidy from the municipality exactly equal to price of collection.

The proper way of modeling (landfill) taxes and (collection) subsidies is by adding a tax term (ξTL) and a subsidy term (ξX) to the welfare function (see equation 3.1) where TL is the total amount of waste to be landfilled, X is the total amount of rest waste generated by households paying a flat fee and ξ is respectively a tax or subsidy wedge per unit of waste[7].

The tax wedge (ξ) is defined as the difference between the equilibrium price for landfilling (p_{ls}) and the price including the tax $(p_{tax,ls})$. The subsidy wedge is defined in the same way. In the flat fee pricing municipalities the perceived price of waste collection (including the subsidy) equals zero, so the subsidy wedge equals the social costs of waste collection. In the unit-based pricing municipalities, the perceived price of waste collection equals the marginal costs of waste collection so the subsidy wedge equals zero.

The total benefits of the subsidy and the costs of the landfilling tax are only added to the social welfare function to change the perceived prices of waste collection and landfilling. It does not imply that introducing subsidies and taxes would positively influence social welfare[8]. Prices are determined by the appropriate balance equations. In the case of landfilling services the balance equation looks like:

$$\mathrm{TL} \le q_{ls} \qquad \perp p_{ls} \qquad (3.3)$$

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[7] See Ginsburgh and Keyzer (1997) for more details on this procedure.

[8] If the model were written in another format, the subsidy would not have to be made explicit in the welfare function. Note that optimal prices and quantities calculated by the model do not depend on the format chosen.

$$\sum_j w_{j,ls} \leq TL \qquad \perp p_{tax,ls} \tag{3.4}$$

Where q_{ls} is the production of landfilling services and $w_{j,ls}$ is the use of landfilling services by municipalities and producers. The equilibrium price of each commodity is determined by taking the marginal value of the corresponding balance equation (this is symbolized by $\perp$p). In the first balance constraint (3.2) the shadow price of landfilling waste is calculated. This price equals marginal production costs. In the second balance constraint (3.3) the shadow price of landfilling including the landfilling tax is calculated

Consumers generate waste by consuming products. Waste generation is dynamic; not all products will be transformed into waste immediately after consumption. Durable goods, for example, can continue to function properly for several years. If one looks at an infinite time scheme, every good will turn into waste. At any point in time, however, only part of the products will be transformed into waste. To include this dynamic aspect in a comparative static model, waste is determined as a fraction β^{g} of the consumption product[9]. Total waste generation per consumer *(W)* is equal to a fixed percentage of total consumption. The government only consumes the goods 'rest economy' and we assume that the government does not generate waste; therefore, in the following equation a subset *c* is used, which encompasses only the private households.

$$W_c = \sum_g \beta_g x_{c,g} \tag{3.5}$$

It is assumed that all waste generated is either collected (x_w) or recycled (x_r), the model does not take into account illegal disposal of any kind.

$$x_{c,r} + x_{c,w} = W_c \tag{3.6}$$

All firms produce commodities y_j within their given production set Y_j. The production set for each of the firms in the model is given by a nested CES production function that depends on the input of capital *(k)*, labor *(l)*, virgin material (m_v), recycled material (m_r) and intermediate inputs (q_g).

Finally, a common requirement in applied general equilibrium models is that demand should equal supply for each commodity in each country. This is ensured in various balance constraints (see for a complete description of the model Bartelings *et al*, 2005).

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9 Implicitly this means that part of the used material accumulates in a stock of durable goods. This stock is not constant, new materials enter the stock and other materials leave the stock as waste. Therefore, at any given moment in time the material inflow does not have to be equal to the material outflow in the model.

3.3 Data: effectiveness of the landfill tax

The model presented in the previous section is used to evaluate the effectiveness of the landfill tax in the Netherlands. We use data for the Netherlands from the year 2002 in this evaluation. The data is gathered from Statistics Netherlands (2003) and the waste management council (2002a, 2002b, 2003a, 2003b, 2003c, 2003d, 2004a and 2004b). The social accounting matrix of the economy is presented in *Table B–1* in appendix B. Supply or producers' output, capital and labour are given as positive values; demand or producer inputs and consumption are given as negative values. To keep the model as simple as possible, government income is dependent on a lump-sum transfer instead of an income from taxes on labour and consumer goods[10]. In the benchmark data set no trade of waste is yet allowed.

In total, consumers and the service sector generated 6,121 ktonne of rest waste in 2002. About 80% of the rest waste stream was incinerated, the rest landfilled. We assume that all waste collected separately is recycled. The service sector in total separated about 1,670 ktonne of waste. Municipalities collected 4,439 ktonne of separated waste.

Consumers living in a flat fee pricing municipality face zero marginal costs for waste generation. This is modelled as if these consumers pay the equilibrium price for waste collection (0.357 million euro per ktonne), however, the government completely reimburses these costs to the consumers in the form of a subsidy. The consumers pay a total amount of 1,343 million Euros for waste collection. In practice, the flat fee charge covers 95% of the actual costs (AOO, 2002a). This means that the actual costs of waste collection and thus the amount spent on the subsidy on waste collection equals roughly 1,414 million Euros.

Since prices of recycling and recycled materials are unavailable, we need a proxy instead. According to AOO (2003d), consumers pay on average €357 per tonne of waste based on a 100% cost-coverage rate. If recycling would be a cheaper option than demanding collection services, a consumer that faces a unit-based price for waste collection would recycle more. Therefore, we assume in the benchmark case that the price of recycling is the same as the price of waste collection[11]. The prices of all other products are normalized to 1, according to the Harberger convention[12].

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[10] As we are interested in the first best equilibrium solution, the existence of distortionary taxes has been ignored.

[11] Note that this deduction of recycling prices is only valid if we assume that consumers have full information and base their recycling decision solely on differences in price level of waste collection and recycling.

[12] Following standard practice, we adopt the Harberger convention in the benchmark data for all unknown prices. The Harberger convention consists of normalizing prices to unity. Quantities in the benchmark data represent expenditures, or how much of that good or factor one can buy for €1.

The amount of recycling by the service sector is determined by the substitution elasticity between capital and labour on the one hand and waste treatment services on the other hand. Based on information about the actual amount of waste recycled and the costs of waste treatment in the period 1995-2003, we estimated the substitution elasticities for the seven service sectors (AOO, 2004b). These substitution elasticities are shown in *Table 3-1*

Table 3-1 Substitution elasticities

	Substitution elasticity waste treatment/ recycling
Wholesale sector	0.37
Retail sector	0.38
Catering sector	0.29
Repairment sector	0.37
Transport sector	0.43
Financial sector	0.42
Other sector	0.31

Substitution elasticities between labour and capital for the different production sectors, between recycled material and virgin material, and between landfilling and incineration are given in *Table 3-2*. The production sectors use capital and labour as inputs for production. They can substitute between the use of capital and labour. Based on Draper and Manders (1996), we choose a substitution elasticity of 0.8.

Table 3-2 Other substitution elasticities

	Production sectors	Municipality
Sub.elas. labour & capital (σ^{kl})	0.8	0.8
Sub.elas. recycled material & virgin material (σ^{vr})	2	
Sub.elas. landfilling & incineration (σ^{il})	0.4	2

Due to the limited capacity of incinerators we assumed that the substitution elasticity between landfilling and incineration is rather small for the service sectors. Municipalities are far more likely to incinerate more waste than firms from the service sector as they often have long-term contracts with waste incineration plants. We, therefore, assume that waste incineration plants will first treat municipal solid waste and will only treat waste from other sources if there is still capacity left.

3.4 Results: effectiveness of landfill taxation

With the general equilibrium model we predict how industries and households react to changes in the landfill tax. We focus attention on how much waste will be landfilled, incinerated, and recycled. In addition we will also analyze how effective the landfill tax is in the presence of market distortions such as limited incineration capacity or flat fee pricing for waste collection.

Figure 3–2a shows how the total amount of waste landfilled or incinerated is affected by the landfill tax rate. The marginal benefits of the landfill tax are high especially in the beginning. A small increase in a low landfill tax rate results in a large decrease in the amount of waste landfilled. The amount of waste incinerated does not increase as much as the amount of waste landfilled decreases, which indicates that households and industries increase recycling. The current tax rate on landfilling in the Netherlands (2005) amounts to €84.78 per tonne, see *Table 2-1*. Due to the limited incineration capacity, incineration cannot increase after a certain level. Given a landfill tax of about €100 per tonne, the complete incineration capacity is filled.

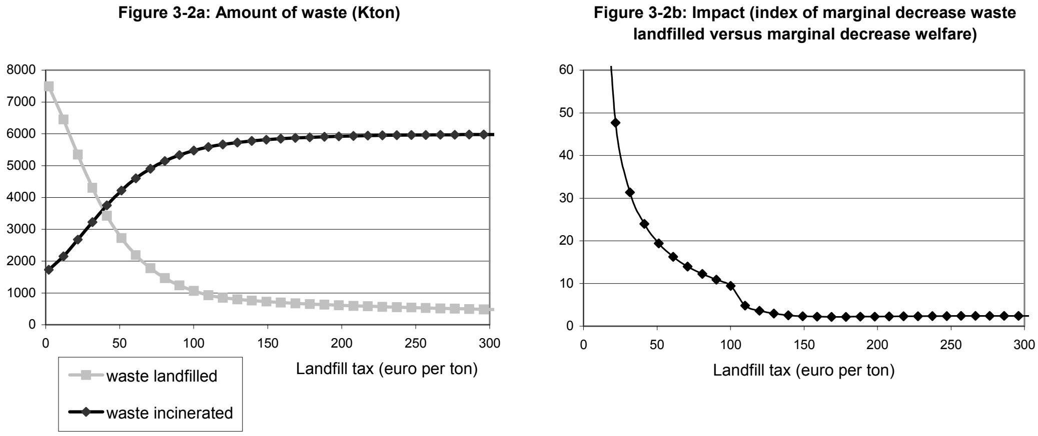

Figure 3-2 Waste treatment and the landfill tax

To evaluate the effectiveness of landfill taxation we compare the benefits of decreased landfilling to the loss of welfare[13]. In order to compare the decrease in waste landfilled to the decrease in welfare, we divide the marginal decrease in waste landfilled by the marginal decrease in welfare of society. *Figure 3-2b* shows that an increase in a low tax rate has a large impact on the amount of waste landfilled but not on the social welfare. However, this impact rapidly decreases with the landfill tax. There is a discontinuity in the impact function around a landfill tax of €100 per ton. This is caused by the limited incineration capacity.

Limited capacity of waste incineration plants and waste export

The impact of limited incineration capacity is further analyzed in *Figure 3-3*, which shows the amount of waste treated for households and industries individually. The difference between household behavior and industries is quite noticeable.

Municipalities, who collect household waste, switch from landfilling to incineration. If the landfill tax is very high, almost all household waste will be incinerated. The

[13] As we do not take into account the external cost of waste treatment, the introduction of a landfill tax will always result in a lower social welfare (measured in total utility from consumption) since a landfill tax will raise prices of production goods and services.

service sector also increases incineration and decreases the amount of waste landfilled. However, *Figure 3-3* shows that the amount of waste landfilled increases again when the tax rises above €100 per ton. This is caused by the limited capacity of incineration plants. Municipalities offer such a large quantity of waste to the incineration plants that the remaining capacity is too small to incinerate all the waste offered to it by the service sector. As a result, the service sector is forced to start landfilling their waste again.

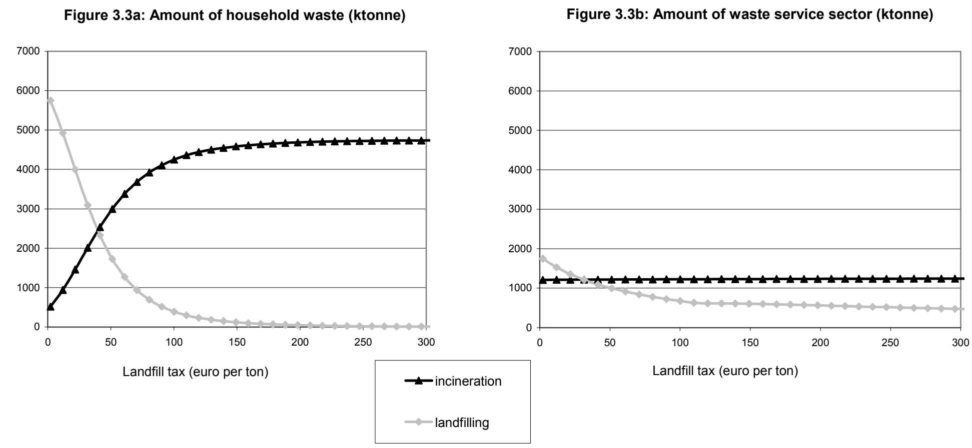

Figure 3-3 Landfilling and incineration of household waste and waste from industries

If we allow trade of combustible waste and effectively lift the limits on incineration capacity, the decline of waste landfilled is similar for the Service sector and the municipalities (*Figure 3–4*).

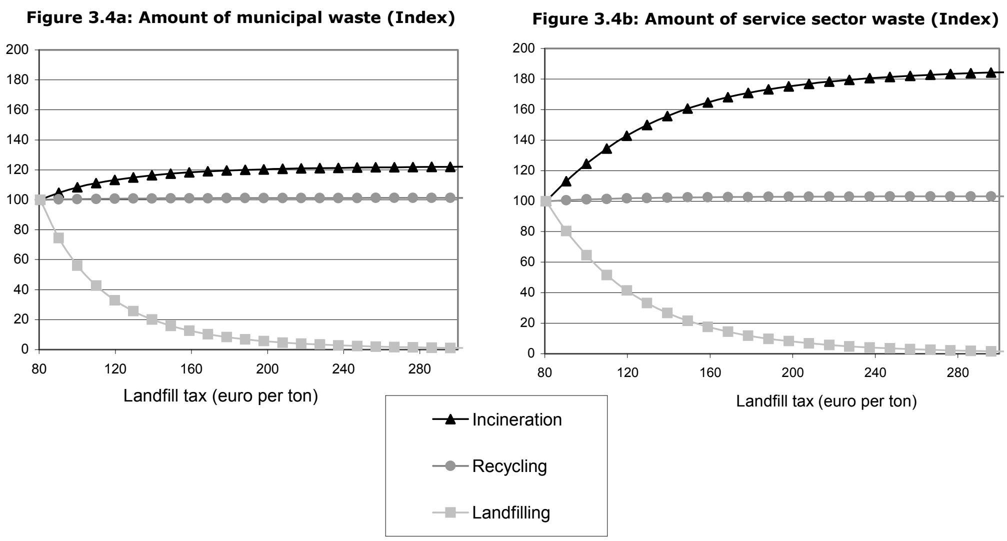

Figure 3-4 Impact of export of combustible waste: results for the Service sector compared to the results of the households (index current tax=100)

Since incineration is slightly more expensive for the service sector -they have to export their combustible waste- the service sector will substitute slightly less waste landfilled for waste incinerated or recycled. Both recycling and waste incinerated increases. The service sector increases recycling more than the households due to the raise in the landfill tax.

Flat fee pricing versus unit-based pricing

Figure 3–5 shows the amount of waste generated and the amount of waste recycled in municipalities. We distinguish between municipalities with unit-based pricing for waste collection (22% of the households in 2002) and municipalities with flat fee pricing (78% of the households). In the municipalities with a unit-based pricing system, households are affected by a higher landfill tax. Since the price they pay for waste collection will increase due to the higher landfill tax, they will increase their recycling efforts. Households living in a municipality with flat fee pricing are not affected by the landfill tax.

Note that we assume a benchmark level of recycling in both types of households. According to our data, households do recycle some of their waste independent of the costs of waste collection. It is clear that other concerns like environmental responsibility play a role in the recycling decision. Recycling levels in a unit-based pricing municipality are generally higher than recycling levels in a flat fee municipality. Only if the landfill tax is between €0-20 per tonne, the price incentive will be so small that the recycling levels of both municipalities are comparable.

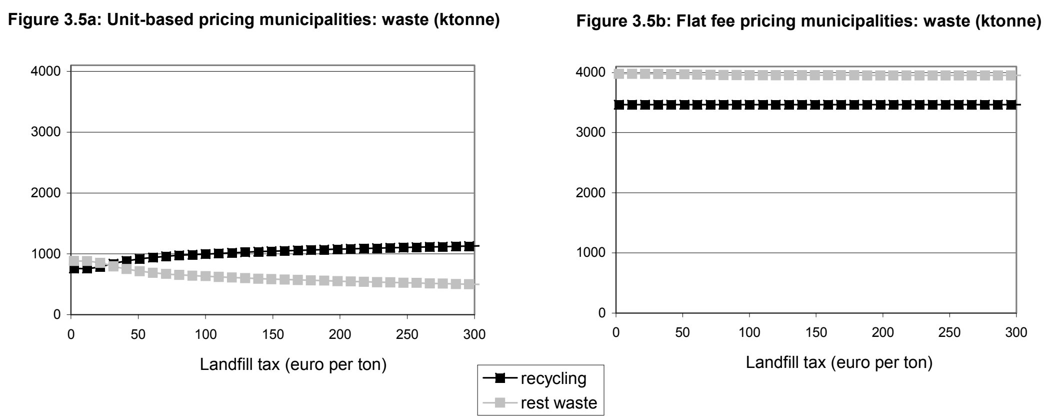

Figure 3-5 Waste generation and recycling in municipalities (in ktonne)

Although it is clear that households living in a municipality with unit-based pricing are more affected by the landfill tax, the question remains what the extra benefit would be if all municipalities introduce unit-based pricing. In *Figure 3–6* we compare the total amounts of waste recycled and waste offered as rest waste in the benchmark data set (partial unit-base price) to the amounts of waste recycled and offered as rest waste in the new scenario where all municipalities turn to unit-based pricing (full unit-based price).

In the full unit-based pricing scenario, more waste is recycled; though the increase in recycling is modest, see *Figure 3–6*. If the landfill tax rate increases from about €80 to €300, the quantity of waste recycled will increase with about 4% in the full unit-based price scenario and with about 2% in the partial unit-based pricing scenario.

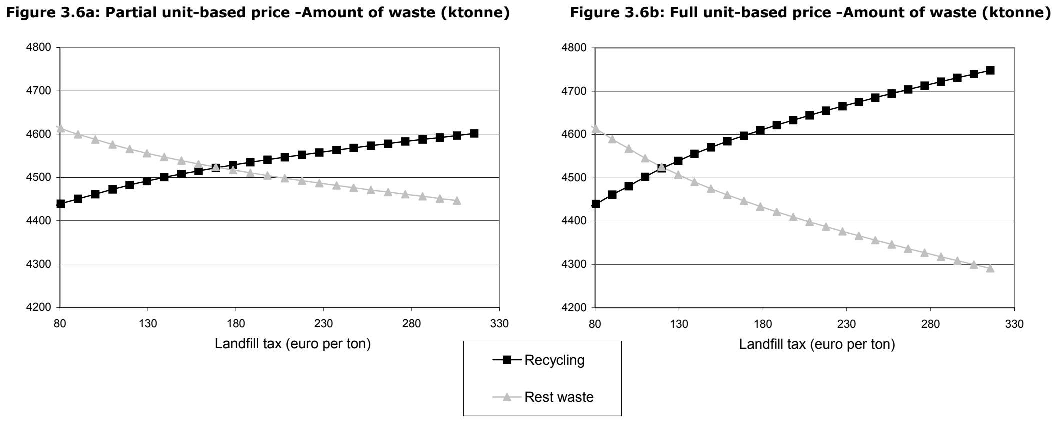

Figure 3-6 Recycling and rest waste: effect of unit-based pricing

4 CONCLUSIONS

In this paper we evaluated the effectiveness of landfill taxation in an ex-post and an ex-ante setting. We used data from the Netherlands as a case study. The *ex post* analysis showed that the landfill tax did not have a significant direct impact on the generation of household waste, nor did it affect the choice for household waste disposal options. However, there may be an indirect effect if municipalities pass on the higher costs of landfilling to households by means of a unit-based price (instead of a 'flat fee') on household waste collection (in 2002, 22% of Dutch municipalities applied such a differentiation). The analysis showed that provinces with a high share of municipalities using unit-based pricing schemes have lower amounts of waste per capita, a lower share of waste landfilled, and a higher share of waste incinerated (even though the choice between landfilling and incineration is not made by the households themselves, but by the municipalities).

For the service sector, the level of disposal costs is not affecting the generation of waste, but it does influence the waste disposal choice. In particular, higher costs for landfilling and incineration increase the share of recycling. Moreover, if the relative increase of costs of landfilling exceeds the relative increase of costs of incineration, firms from the service sector will landfill less waste and incinerate more. In this sense, the landfill tax can play a crucial role in the decision making of firms from the service sector with respect to disposing of waste.

The *ex ante* effectiveness of landfill taxes was assessed by means of a general equilibrium model. The results of the 'benchmark scenario' showed that a landfill tax has a significant effect on the amount of waste landfilled. The higher the landfill tax the more waste will be recycled or incinerated. The model predicted that municipalities start to incinerate all their waste if the landfill tax becomes too high. Only in municipalities that charge a unit-based price for waste collection will households directly notice the effects of the landfill tax by an increase in the price for waste collection and thus start to recycle more waste. In municipalities that charge a flat fee for waste collection, the model showed that households do not have an incentive to recycle more waste. Recycling efforts, however, are low regardless of the pricing system for waste collection. The increase in the landfill tax will only provide a modest incentive to recycle. Most of the municipal solid waste is already incinerated so the price increase of waste collection due to the landfill tax will be slight.

The service sectors, in contrast to the municipalities, choose (according to the model calculations) to recycle more waste. Some sectors slightly increase their demand for waste incineration services, but the biggest difference in the service sectors is the amount of waste that is recycled. This is mostly caused by the fact that, similar to the Dutch situation, the incineration capacity in the model is too small to accept both an increased amount of municipal solid waste and an increased amount of service waste. If export of combustible waste is allowed, then the service sector will also increase the amount of waste they incinerate. Export of combustible waste will slightly reduce the recycling effort of the service sector.

An increase in the landfill tax will decrease the social welfare, i.e. measured in terms of consumption. The impact analysis shows a relatively large decrease in waste landfilled combined with a relatively low decrease in welfare if the landfill tax is increased from a low level to a slightly higher level. If the landfill tax is higher (for example higher than €100 per tonne), the decrease of waste landfilled is much lower compared to the loss of welfare.

Both the ex-ante as the ex-post analysis suggest that the present landfill tax rate of almost € 85 per tonne in the Netherlands is an effective measure to turn waste suppliers to alternatives. As long as the Dutch government prefers to base their waste policy on the waste hierarchy which states that landfilling is the least preferred waste treatment option, maintaining a landfill tax especially such a high one is the most effective option. Increasing the landfill tax further will be too expensive in terms of social costs. However, one must keep in mind that due to other restrictions, such as a lack of incineration capacity or a strict regulation on the export of waste, landfill taxation will not eliminate landfilling completely.

REFERENCES

AOO (2000). Voortgangsnotitie verdeelplan overschot brandbaar afval jaaroverzicht 1999. AOO 2000-04. Utrecht: Afval Overleg Orgaan.

AOO (2003a) The waste market: the Netherlands and neighboring countries. AOO 2003-12. Utrecht: Afval Overleg Orgaan.

AOO (2003b) Monitoring rapportage huishoudelijk afval. AOO 2003-16. Utrecht: Afval Overleg Orgaan.

AOO (2003c) Afvalverwerking in Nederland: gegevens 2002. AOO 2003-18. Utrecht: Afval Overleg Orgaan.

AOO (2003d). Gemeentelijke afvalstoffenheffingen in 2003. AOO 2003-11. Utrecht: Afval Overleg Orgaan.

AOO (2004a). Afvalstoffenheffingen 2004. AOO 2004-10. Utrecht: Afval Overleg Orgaan.

AOO (2004b). Bedrijfsafval uit de KWD-sector: meting 2003. AOO 2004-16. Utrecht: Afval Overleg Orgaan.

Bartelings, H., P. van Beukering, O. Kuik, V. Linderhof and F. Oosterhuis (2005) Effectiveness of landfill taxation. Amsterdam: Institute for environmental studies.

Calcott, P. and Walls, M., 2002, Waste, recycling and design for the environment: roles for markets and policy instruments, Resources for the Future Discussion Paper 00-30REV, Resources for the future, Washington.

Dijkgraaf, E. (2004). Regulating the Dutch Waste Market. Studies in Economic Policy 14. PhD thesis Erasmus University Rotterdam. 217 pp.

Draper, N. and T. Manders (1996). Structural changes in the demand for labor. CPB-report no 128, The Hague: Centraal Planbureau.

Ginsburgh V. and M. Keyzer (1997) The structure of applied general equilibrium models. London: The MIT Press.

Jenkins R.R. (1993), The economics of solid waste reduction, the impact of users fees. Aldershot: Edward Elgar.

Hong, S.R., Adams, M., and Love, H.A., 1993, An economic analysis of household recycling of solid waste: the case of Portland, Oregon Journal of Environmental Economics and Management, 25, 136-146.

Kinnaman, T.C., and D. Fullerton (2000), The economics of residential solid waste management. In: T. Tietenberg and H. Folmer (eds.) The international yearbook of environmental and resource economics 2000/2001. Cheltenham: Edward Elgar.

Miranda, M. L., J.W. Everett, D. Blume and A.R. Barbeau Jr. (1994), Market-based incentives and residential municipal solid waste. Journal of Policy Analysis and Management, 13(4), p. 681-698.

Morris, G.E. and D.M. Holthausen (1994), The Economics of Household Solid Waste Generation and Disposal. Journal of Environmental Economics and Management, 26, p. 215-234.

Statistics Netherlands (2003) National accounts of the Netherlands, Statistics Netherlands, Voorburg.

Sterner, T. and Bartelings, H., 1999, Household waste management in a Swedish municipality: determinants of waste disposal, recycling and composting, Environmental and Resource Economics, 13, 473-491.

Appendix A Summary statistics of household and service sector data

Table A.1 Summary statistics of dataset on household waste per province, 1995-2003.

Variable description	Mean	Std. Dev
Remaining landfill capacity (10^6 m^3)	5.4	3.9
Landfill tariffs including landfill tax (€ per ton)	97.3	18.0
Waste incinerated (kton)	372.8	534.8
Incineration capacity (kton)	353.9	546.5
Rest capacity of incineration plants (kton)	658.0	228.1
Incineration tariff (€ per ton)	102.8	7.5
Disposed household waste (kton)		
Landfilled	80.4	127.1
Incinerated	241.6	294.3
Recycled or composted	384.1	239.9
Population (x 1000)	1,323.0	961.7
Population density	475.0	323.7
Total number of households (x 1000)	566.2	426.5
Number of single person households (x 1000)	189.5	160.9
Gross Domestic Product (10^9 €)	31.27	25.44
Annual volume growth of GDP (%)	2.5	2.4
Annual deflation of GDP (%)	2.6	1.9
Number of municipalities		
Without unit-based schemes	33.2	23.8
With unit-based schemes	9.8	11.3
Waste disposal charge (€ per household)	192.3	14.6

Sources: CBS, AOO, RIVM.

Table A.2 Summary statistics of dataset on waste supplied by service sub-sectors, 1995-2002.

Variable description	Mean	Std. Dev
Total waste (kton))	696.4	461.9
Landfilled (kton)	243.2	165.6
Incinerated (kton)	159.8	113.4
Recycled (kton)	293.4	200.4
Waste not collected separately (kton)	403.1	243.4
Landfill capacity (106 m3)	66.2	9.3
Number of landfills in NL	39.3	6.0
Landfill tariff including landfill tax (€ per ton)	93.0	21.3
Incinerated waste (kton)	4385.4	765.2
Incineration capacity (kton)	5067.8	742.1
Rest capacity of incineration plants (in kton)	682.4	232.4
Number of waste incineration plants in NL	10.3	1.4
Incineration tariff (€ per ton)	101.2	6.4
Value added (VA) (109 €)	48.28	32.37
Annual volume growth of VA (%)	3.7	3.2
Annual deflation of VA (%)	2.5	3.0
Employment (103 men years)	792.9	507.5
Number of firms (x 1000)	105.9	63.6

Sources: AOO, CBS, RIVM.

Appendix B

Table B–1 Benchmark data input-output model (waste sectors in ktonne, other sectors in million euro)

	Whole-sale	Retail	Cater-ing	Repair-ment	Transport sector	Financial	Other	Rest economy	Virgin mate-rial	Recycled material	Recycling Services	Collection waste	Landfill	Incin-era-tion	Con-sumer 1	Con-sumer 2	Govern-ment	Price
Wholesale sector	18136	0	0	0	0	0	0	0	0	0	0	0	0	0	-14872	-3264	0	1,000
Retail sector	0	11010	0	0	0	0	0	0	0	0	0	0	0	0	-9028	-1982	0	1,000
Catering sector	0	0	3679	0	0	0	0	0	0	0	0	0	0	0	-3017	-662	0	1,000
Repairment sector	0	0	0	5238	0	0	0	0	0	0	0	0	0	0	-4295	-943	0	1,000
Transport sector	0	0	0	0	34376	0	0	0	0	0	0	0	0	0	-28188	-6188	0	1,000
Financial sector	0	0	0	0	0	32965	0	0	0	0	0	0	0	0	-27032	-5934	0	1,000
Other sector	0	0	0	0	0	0	5859	0	0	0	0	0	0	0	-4804	-1055	0	1,000
Rest economy	-77	-86	-47	-27	-34	-82	-77	10429	0	0	0	0	0	0	0	0	-10000	1,000
Virgin material	0	0	0	0	0	0	0	-5000	5000	0	0	0	0	0	0	0	0	1,000
Recycled material	0	0	0	0	0	0	0	-2642	0	2642	0	0	0	0	0	0	0	1,000
Recycling Services	0	0	0	0	0	0	0	0	0	0	4439	0	0	0	-3464	-975	0	0,357
Recycled waste	0	0	0	0	0	0	0	0	0	-4439	4439	0	0	0	0	0	0	0,357
Collection waste	0	0	0	0	0	0	0	0	0	0	0	4614	0	0	-3959	-654	0	0,357
Landfill	-131	-143	-109	-49	-53	-134	-160	0	0	0	0	-575	1353	0	0	0	0	0,049
Incineration	-205	-224	-171	-78	-84	-210	-251	0	0	0	0	-3546	0	4768	0	0	0	0,117
Capital	-2817	-2386	-715	-1636	-18730	-4585	-1060	-787	-4750	-266	-797	-447	-35	-546	32424	7133	0	1,000
Labour	-15199	-8490	-2879	-3559	-15593	-28253	-4668	-2000	-250	-791	-2373	-670	-43	-61	69560	15269	0	1,000
Transport cost	-3	-4	-3	-1	-1	-3	-4	0	0	0	0	-42	49	12	0	0	0	1,000
Fee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1343	0	1343	1,000
Subsidy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1414	0	-1414	1,000
Tax	-11	-11	-9	-4	-4	-11	-13	0	0	0	0	-46	0	0	0	0	109	1,000
Lumpsum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8169	-1793	9962	1,000

Note: 'Fee' is the flat fee consumers pay to the government for collection of waste, 'Subsidy' is the total amount of money the government gives for collection of waste as a subsidy to the consumers. 'Lumpsum' is for a lumpsum transfer from the consumers to the government. The price column represents the prices of all commodities.