Modeling market distortions in an applied general equilibrium framework: the case of flat fee pricing in the waste market

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Abstract

This paper deals with modeling of market distortions in general equilibrium models. It focuses specifically on the problems associated with flat fee pricing in the waste market. A general equilibrium model for the waste market is presented and it is described in detail how flat fee pricing can be introduced in the Negishi format. A numerical example has been used to demonstrate the effects flat fee pricing can have on the generation of waste. The results show that flat fee pricing can have significantly negative effects on waste generation. They further show that policies promoting recycling can not be effective unless they are combined with the introduction of variable prices for waste collection.

Keywords: waste management; inefficiencies; general equilibrium modeling; Negishi format

1 Introduction

Current waste management policies are not sufficient to obtain a significant reduction in waste generation of both industries and households. Although the government has put a lot of effort into waste reduction, the amount of waste generated still rises. This is mostly due to economic growth. The government has failed to achieve a decoupling between waste generation and economic growth, one of the goals of the government, due to characteristics of the waste market. Some of these characteristics of the waste market are flat fee pricing, environmental regulations, which unintentionally promote the use of virgin material instead of recycled material and contracts between municipalities and waste treatment facilities.

Several studies have been conducted to analyze the effects of market distortions in the waste market and to suggest solutions. Most of these studies used a partial approach. Wertz (1976) was the first to estimate the effects of a user charge on solid waste disposal. Other more recent studies are Jenkins (1993), Hong et al. (1993), Miranda et al. (1994) Morris et al. (1994) and Sterner and Bartelings (1999). The overall conclusion of these empirical analyses is that the demand for waste services is sensitive to user fees and that the introduction of (higher) user fees can cause a

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substantial reduction in waste production. However, thoughtless construction of waste handling tariffs might not have the desired effect and can encourage illicit dumping, burning or other improper disposal: see e.g. Fullerton and Kinnaman (1995). In Miedema (1983) the effects of other distortionary characteristics of the waste market, like virgin material-biased tax policies, virgin material-biased regulations and indirect subsidization of virgin materials are analyzed.

In this paper, the distortionary effects of flat fee pricing are analyzed. The flat fee pricing scheme means that private households do not pay a variable price for waste collection. Instead they pay a fixed tax (flat fee) for waste collection regardless of the amount of waste they actually generate.

This paper deals with how a flat fee pricing system for consumer-generated waste can be modeled in an applied general equilibrium (AGE) model in the Negishi format. It is written as a methodological paper, and assumes some basic knowledge on applied general equilibrium modeling. The modeling technique used is an application of existing theory (see for example Ginsburgh and Keyzer, 1997). The methodology proposed in this paper will be used in an empirical setting in Bartelings et al. (2001).

The paper is laid out as follows: first, the problems associated with flat pee pricing are discussed. Then, the AGE model of the waste market is presented. Special attention is given to how a flat fee pricing scheme can be introduced in the Negishi format. Section 4 presents a numerical example, in which the consequences of flat fee pricing are calculated for a hypothetical economy. Finally section 5 concludes.

2 General description of the problem associated with flat fee pricing

Since most households in the Netherlands pay a fixed amount of money for waste collection through taxes, the amount of money they pay for waste collection is independent of the amount of waste they actually generate. This means that the actual perceived price for waste collection, in economic terms the marginal costs of generated waste, equals zero. The problem with a zero price for a good is that the amount of waste that will be generated cannot be determined through the normal demand and supply functions. Especially in the general equilibrium framework, where it is assumed that some equilibrium price will make sure that demand equals supply, the zero price poses a problem. Hence, in order to implement a zero price in a general equilibrium model we need some indirect approach. It is possible to implement a zero perceived price by using subsidies that compensate the households for their costs for waste generation (Fullerton and Wu, 1998)

The households pay a fixed lump-sum transfer (direct tax) for waste collection to the government. This lump-sum transfer takes away part of the income of the households. Total expenditure of the households goes down. The expenditure pattern, i.e. the percentage of income the households spend on a certain product will, however, not be affected.

The households demand waste collection services and will pay an equilibrium price for these services. However, they receive a subsidy, which exactly equals the equilibrium price, for every unit of waste collection services. Thus, the perceived price of waste collection for the households equals zero. If the revenue of the lump-sum transfer is lower than the amount spent on the subsidy, the government expenditure will go down (i.e. there is a net subsidy on waste generation). If the revenue of the fixed fee is higher then the total costs, government expenditure will rise. In the next section, it will be discussed how such a subsidy-cum-lump-sum transfer scheme can be implemented in a general equilibrium model.

3 Description of the model

In this section the applied general equilibrium model of the waste market is presented. A general equilibrium model with endogenous prices is far more straight forward then a model with price distortions. Therefore, to enhance understanding of general equilibrium modeling, first of all a model describing the waste market with variable prices for all commodities will be presented. Then secondly, it will be discussed how the model with variable prices should change in order to introduce flat fee pricing. Lastly some comments will be given about the welfare implications that can be deducted from this type of modeling.

There are several ways (or formats) to present general equilibrium models including the Arrow-Debreu format, the Computable General Equilibrium format, the open economy format, the full format and the Negishi-format. Some of these formats are written in terms of excess demands, other in terms of welfare programs. Extensive information about the strength's and weaknesses of each of these formats can be found in Ginsburgh and Keyzer (1997). However it should be stressed that the format is just a way of representing a model. A different format still describes the same model and will result in the same equilibrium as another format.

In this paper the Negishi-format is chosen as the preferred tool for building a general equilibrium model of the waste market. The Negishi format has as advantage that it is relatively easy to incorporate externalities and non-convexities (see also Ginsburgh and Keyzer, 1997). Hence it is especially suitable to incorporate externalities of waste treatment in the model and market distortions like flat fee pricing and contracts between municipalities and waste treatment facilities.

3.1 Description of the model with a variable price for waste collection

In a simplified economy two types of actors are distinguished: households and firms. Households consume goods and supply endowments; firms produce goods and use endowments and intermediate goods. Two types of households are distinguished: private consumers and a government consumer. Eight different types of firms are distinguished, each producing one unique good. These firms are ordered in the following sectors: a extraction sector producing virgin material; a production sector producing agricultural goods, industrial goods and services; a recycling sector producing recycling services; a collection sector producing collection services and a waste treatment section producing incineration services and landfilling services. In Figure 1 the hypothetical economy is shown.

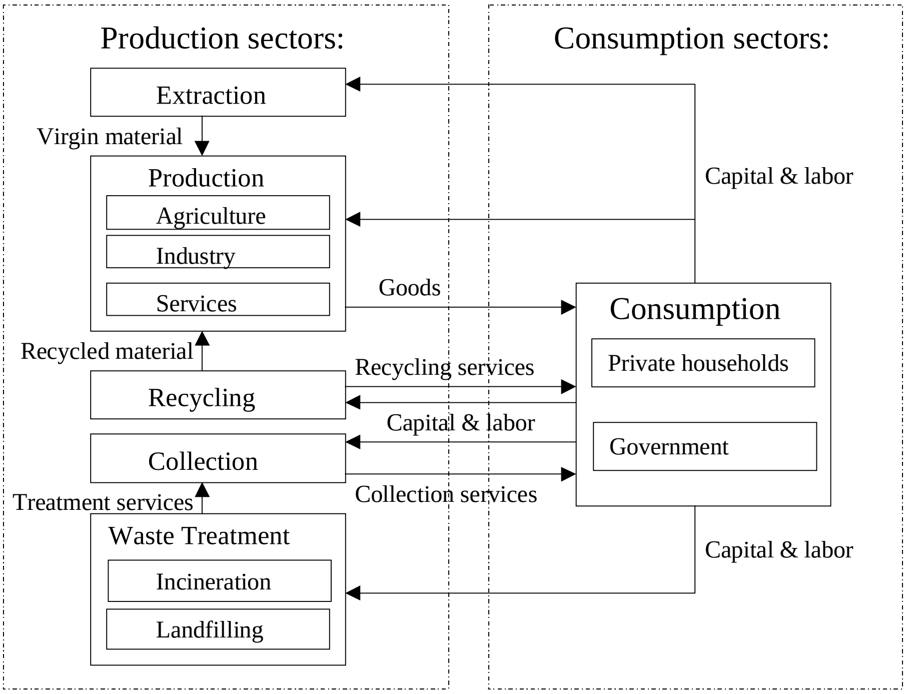

Figure 1 Representation of the hypothetical economy

The households supply two types of endowments (capital and labor) to the firms. In exchange they get money (interest and wages) for these factors, which they use to buy consumer goods.

The private households consume three types of consumer goods. They consume agricultural goods, industrial goods and services. The government consumes only services. The consumption of the private households will generate waste. This waste has to be dealt with. It can either be recycled or the municipality can collect it. The government consumer does not generate any waste.

All the firms produce goods or services with the use of capital and labor as inputs. The extraction sector produces virgin material, which is sold to the production sector of consumer goods. The recycling sector sells recycling services to the consumer and recycled material to the production sector of consumption goods. Besides capital and labor, the production sector of consumer goods uses virgin material and recycled material as inputs for production. The collection sector sells collection services to the consumers. They use capital and labor and waste treatment services as input for production. Finally the waste treatment sector consists of two producers: producer of incineration services and producer of landfilling services. The waste treatment sector sells waste treatment services to the collection sector.

3.1.1 Consumer utility function

The model is written in the Negishi format. The benchmark model (without flat fee pricing) closely resembles standard general equilibrium modeling in the Negishi format. More information about this type of modeling and the prove that the solutions calculated by these model are indeed general equilibria can be found in for example

Ginsburgh and Keyzer (1997) and Negishi (1972). In this format, the typical way of modeling is that total welfare (the weighted sum of utilities of all consumers) is maximized subject to certain balance constraints. The total welfare function is shown in equation 3.1. Total welfare (TW) equals the sum of the weighted utilities (u_i)

$$TW(\alpha_i) = Max \sum_i \alpha_i u_i (x_i^g) \qquad \textbf{(3.1)}$$

The utility of each consumer is weighted by a factor α, the so-called Negishi weight. These Negishi weights are determined in such a way that each consumers budget constraint holds. This means that each consumer can not spend more money on goods and services then they receive for the sales of primary inputs (capital and labor). How these Negishi weights are determined in the model and how the equilibrium solution is found is described in appendix A.

It is assumed that the utility of the households depends on the consumption of goods (x_i^g). Consumption of goods will generate waste. This commodity waste can be modeled in to ways. Either the waste can be regarded as a negative externality of consumption or the demand for waste treatment services can be seen as a necessary input in the utility function. If the latter method is chosen then in the utility function some positive weight is given to the consumption of waste treatment services (i.e. waste collection or waste recycling). In order to be able to consume goods the households have to consume waste treatment services as well. In the case of modeling waste as a negative externality with a zero price some extra precaution are necessary to ensure that an equilibrium is found. If however waste is modeled as a necessary input in the utility function, demand for waste treatment services will be no different for "normal" commodities and an equilibrium price can be calculated (Ginsburgh and Keyzer, 1997).
The consumption of goods and the consumption of waste treatment services are assumed to be strictly complementary, so a Leontief structure is chosen for the utility function:

$$u_i = min(x_i^g, g(r_i, w_i)) \qquad \textbf{(3.2)}$$

where x_i^g stands for the consumption of good g by consumer i and $g(r_i,w_i)$ is the aggregate of recycling services (r_i) and collection services (w_i), which are to some extent substitutable. A CES-structure is assumed for the waste treatment function $g(r_i,w_i)$. Since it is assumed that the government does not generate any waste, the utility function for the government will solely depend on the consumption of goods.

3.1.2 Production functions

The eight types of producers (virgin material, consumer goods, recycling services, collection services and waste treatment services) will use the primary factors capital (k) and labor (l) and intermediate inputs like virgin material (m^v), recycled material (m^r) and waste treatment services (w) in order to produce goods. It is assumed that all producers will produce commodities y_j within their given production set Y_j. The production set Y_j is given by a CES production function $f(k,l,m^v,m^r,w)$ which depends on the input of capital, labor, virgin material, recycled material and waste treatment services.

$$y_j \in Y_j$$
$$Y_j = f(k_j, l_j, m_j{}^v, m_j{}^r, w_j) \quad \textbf{(3.3)}$$

3.1.3 Balance equations

Like in all general equilibrium models one of the conditions is that the demand for commodities (consumed goods and primary factors) is equal to the supply of these commodities (produced goods and endowments). This is ensured by the following balance equations.

First of all, total demand for consumer good *g* must be equal to or less than total supply *(y^g)* of consumer good *g* where *g* is an index of the three consumer goods: agricultural goods, industrial goods and services. The shadow prices of the commodities can be determined from the balance equations, in the following equations, this is symbolized by the '$\perp$' and a price variable *p*.

$$\sum_i x_i^g \leq y^g \qquad \perp p^g \qquad \textbf{(3.4)}$$

Total demand of all firms *j* for the intermediate good "virgin material" *($m_j{}^v$)* must be equal to or less than total supply of virgin material *(y^v)*. Since recycled material is an intermediate goods which is not demanded by the households the only demand comes from firm *j*.

$$\sum_j m_j^v \leq y^v \qquad \perp p^v \qquad \textbf{(3.5)}$$

Total demand for the intermediate good "recycled material" *($m_j{}^r$)* must be equal to or less than supply of recycled materials *(y^r)*

$$\sum_j m_j^r \leq y^r \qquad \perp p^r \qquad \textbf{(3.6)}$$

Total demand for the good "recycling services" *(r_i)* must be equal to or less than total supply of recycling services *(y^{rs})*.

$$\sum_i r_i \leq y^{rs} \qquad \perp p^{rs} \qquad \textbf{(3.7)}$$

Total demand for the good "waste collection services" *(w_i)* must be equal to or less than total supply of waste collection services *(y^w)*.

$$\sum_i w_i \leq y^w \qquad \perp p^w \qquad \textbf{(3.8)}$$

Total demand for the intermediate good "waste treatment service" *($wts_j{}^n$) n* (incineration or landfilling) must be equal to or less than total supply of waste treatment services.

$$\sum_j wts_j^n \leq y^n \qquad \perp p^n \tag{3.9}$$

Total demand of primary factors must be equal to or less than total supply of primary factors $(\overline{k},\overline{l})$. Total supply of capital and labor is equal to the sum of initial endowments of each consumer.

$$\sum_j k_j \leq \sum_i \overline{k_i} \qquad \perp p^k \tag{3.10}$$

$$\sum_j l_j \leq \sum_i \overline{l_i} \qquad \perp p^l \tag{3.11}$$

Prices for all commodities equal the marginal value of the associated balance equations. These prices are used in calculating the optimal Negishi weights. Negishi weights are calculated in such a way that each consumer's budget restriction holds (equation 3.12). The consumer obtains income by selling production factors capital and labor and spends its income on the three consumer goods, recycling services and waste collection services.

$$\sum p^g x_i^g + p^r r_i + p^w w_i = p^k \overline{k_i} + p^l \overline{l_i} \tag{3.12}$$

3.2 Description of the model with a fixed price for waste collection

In order to implement the subsidy -cum-lump-sum transfer scheme as discussed in the first paragraph we can extend the objective of the welfare function with subsidy terms (see Ginsburgh and Keyzer, 1997, for details on this procedure). These subsidy terms work like benefits on the production allocation. Maximum social welfare now depends on the weighted utility of consumer *i* on the one hand and on the total benefits of the subsidy (ξW) on the other hand. These benefits can be seen as an extra consumer who contributes to social welfare and who has a weight equal to the subsidy wedge (ξ).

$$TW(\alpha) = \max \sum_i \alpha_i u_i (x_i^g, w_i, r_i) + \xi \ W$$
$$x_i^g \geq 0 \ , \ w_i \geq 0, \ r_i \geq 0 \ \ all \ i \ , \ y_j \ all \ j \tag{3.13}$$

Technically speaking, the higher the subsidy given to the households, the higher the social welfare will be. The presence of the subsidy in the welfare function is for technical reasons and specific to the Negishi format of the model, which does not contain explicit modeling of the budget constraints of the consumers insight the model. The budget constraint is only used to calculate the Negishi weights (see appendix A). If the model were written in another format, the subsidy would not have to be made explicit in the welfare function (and keep in mind that the results of the model do not depend on the format chosen).

The utility function of the private households is calibrated in order to reproduce the benchmark data. The utility function of the private households is shown in the following equation:

$$u_c = \min(x_c, g(r_c, w_c))$$

$$\text{where } g(r_c, w_c) = \overline{x_c}\left[\theta_r\left(\frac{r_c}{\overline{r_c}}\right)^{\rho} + \theta_w\left(\frac{w_c}{\overline{w_c}}\right)^{\rho}\right]^{\frac{-1}{\rho}} \qquad \textbf{(3.14)}$$

$$\theta_r = \frac{p^r \overline{r_c}}{p^r \overline{r_c} + p_c^w \overline{w_c}}, \quad \theta_w = \frac{p_c^w \overline{w_c}}{p^r \overline{r_c} + p_c^w \overline{w_c}}$$

Since the price for waste collection minus the subsidy *(*p_c^w*)* is equal to zero, the share of waste collection *(*θ_w*)* in the utility function is equal to zero. That means that the utility function for the consumer can be substituted with:

$$u_c = \min(x_c, r_c) \qquad \textbf{(3.15)}$$

So a direct relation is implicitly assumed between consumption and recycling.

The balance equation for waste collection services (equation 3.8) is rewritten as follows:

$$W \le y^w \qquad \perp p^w \qquad \textbf{(3.16)}$$

$$\sum_i w_i \le W \qquad \perp p_c^w \qquad \textbf{(3.17)}$$

One new variable is introduced: total waste demand *(W)*. In the first balance equation (equation 3.16), the shadow price of waste collection is calculated. This price equals production costs. In the second balance equation (equation 3.17), the shadow price of waste treatment services, as the consumers perceive it, is calculated. This is equal to the equilibrium price minus the subsidy. In our case this perceived price equals zero. Note that mathematically speaking, the introduction of the total waste demand variable is irrelevant ($W = \sum_i w_i$ can be substituted in the balance equation in the equilibrium solution). However, the distinction of W enables the separation of the social (equilibrium) price for waste collection and the perceived price (which equals zero for the households).

The Negishi weights *(*α_i*)* are determined in such a way that every consumer is on its budget constraint. The budget constraint for the private households *c* looks as follows:

$$\sum_g p^g x_c^g + p^r r_c + p_c^w w_i + LST_c = p^k k_c + p^l l_c \qquad \textbf{(3.18)}$$

Private households spend their income on the consumption of consumer goods, recycling services and collection services (keep in mind that p_c^w is zero so the costs of consumption of waste collection services is equal to zero) and pay a lump-sum transfer *(LST)* to the government for the collection of waste.

The budget constraint of the government looks as follows:

$$\sum_g p^g x_{gov}^g + S = p^k k_{gov} + p^l l_{gov} + LST_c \qquad \textbf{(3.19)}$$

The government spends its income on consumer goods and the subsidy costs *(S)*. It does not spend any income on recycling and collection since it does not generate any waste. The income of the government is earned by selling primary factors and the benefits of the lump-sum transfer.

The size of the subsidy costs depends on the total amount spent on the subsidy for waste collection, which is calculated as follows:

$$S = \xi \sum_i w_i \qquad \textbf{(3.20)}$$

The total transfer equals the subsidy wedge *(ξ)* multiplied by the total demand for waste collection services. The subsidy wedge is calculated as follows:

$$\xi = p^w - p_c^w \qquad \textbf{(3.21)}$$

The subsidy wedge is equal to the real price of waste collection minus the perceived price of waste collection. In our case the perceived price of waste collection equals zero so the price wedge equals the real price of waste collection.

3.3 Welfare implications

As already mentioned in section 2, the expenditure of the government is variable. If the flat fee paid by the households for waste collection is too low compare to the costs, government expenditure goes down. If the flat fee is too high, government expenditure goes up (see equation 3.19). Only if the total flat fee is exactly equal to the total costs of the subsidy will the government income and expenditure not be affected.

Changing government expenditure can have income effects for private households. This is called the incidence of public expenditure. When government expenditure changes, this will likely have an effect on the relative prices in the economy. The relative prices of factors of production and the relative prices of final consumption and production goods will change. Changes in relative prices will affect the income of private households directly through changed prices for production factors and indirectly through changing prices of consumption goods. Thus changing public expenditure has some effects on the income distribution of private households and the utility of private households (Brown and Jackson, 1990).

When the government expenditure is allowed to change, it becomes difficult to make statements about the welfare effect of a certain policy since the welfare of the consumer is affected by the expenditure change of the government. If one is interested in welfare changes of for example the introduction of a certain tax, either the government budget or the government utility should be kept constant or government utility should change exactly identical to the change in utility of the private households (see Keller (1979), Brown and Jackson (1990) for further information).

However in the model described above it is essential to vary government expenditure in the case of changing policies. Suppose that the government expenditure is kept constant. If through some policy change the waste generation of private households is lowered than the costs of the subsidy is lowered. This means that in order to keep the government budget constant some of the avoided costs must be transferred to the private households. That means that the private households now have a direct incentive to lower their waste production. The less waste they generate, the more money they get from the government as a direct lump-sum transfer. The key of the flat fee for waste collection however is that there is no direct link between waste generation and the price of waste collection. So it is not possible to keep government expenditure constant.

Since it is difficult to distinguish between the direct welfare effects of the policy and the indirect welfare effects of the government expenditure incidence, it is difficult to make statement about the individual welfare effects for households of policy changes. However the overall welfare effects can still be described and it can still be shown how cost-effective policy changes are and how policy changes will affect the amount of waste generated.

4 A numerical example

The model discussed above is tested with a numerical example. The main goal of this section is to show how the main mechanisms of the model operate and how these mechanisms are influenced by the assumptions inherent in the model. The economic data used in the numerical example are roughly based on the economy in the Netherlands in 1996.

4.1 Parameter values used in numerical example

The accounting matrix displayed in Table 1 describes the initial equilibrium.
Producers' output and consumer endowments are given positive values, producer inputs and consumption are given negative values. The prices of all commodities are normalized to unity. The column of each producer sums to zero to ensure that the zero profit condition holds (value of input equals value of output). The column of each consumer sums to zero to ensure that the budget constraint holds (each consumer spend exactly its income on the consumption of goods and services). Each row must sum to zero in order to ensure that each market clears (total demand for each commodity must equal total supply).

Table 1 Benchmark social accounting matrix

	Agri	Indu	Serv	Extr	Rm	Rec	Col	Incin	Land	Priv	Govt	Colsum	price
Agri	400	-180	-10	0	0	0	0	0	0	-210	0	0	1
Indu	-120	2200	-480	0	0	0	0	0	0	-1590	0	0	1
Serv	-40	-570	5270	0	0	0	0	0	0	-4460	-200	0	1
Extr	-10	-327.5	-20	347.5	0	0	0	0	0	0	0	0	1
Rm	0	-2.5	0	0	2.5	0	0	0	0	0	0	0	1
Rec	0	0	0	0	0	2.5	0	0	0	-2.5	0	0	1
Col	0	0.0	0	0	0	0	10	0	0	-10	0	0	1
Incin	0	0.0	0	0	0	0	-6	6	0	0	0	0	1
Land	0	0.0	0	0	0	0	-2	0	2	0	0	0	1
K	-180	-470	-1970	-270	-1.5	-0.5	-1	-5	-1.5	2699	200.5	0	1
L	50	-650	-2790	-77.5	-1	-2	-1	-1	-0.5	3573	0	0	1
fee	0	0	0	0	0	0	0	0	0	-9.5	9.5	0	1
subsidy	0	0	0	0	0	0	0	0	0	10	-10	0	1
rowsum	0	0	0	0	0	0	0	0	0	0	0	0	

Note: "Agri", "Indu" and "Serv" indicate the three producer sectors of consumer goods (Agriculture, Industry and Services); "Extr" indicates the extraction sector, "Rm" indicates the production sector of recycled material and "Rec" indicates the production sector of recycling services; "Col" is the collection sector, "Incin" indicates the production sector of incineration services and "Land" indicates the production sector of landfilling services; K and L stand for the primary production factors capital and labor; fee is the flat fee consumers pay to the government for waste collection, subsidy stands for the total amount of money the government gives for waste collection as a subsidy to the consumers. The price column gives the prices of all commodities; Rowsum is the sum of a column, Colsum is the sum of each row.

It is assumed that the production sectors do not generate waste, only the consumer sector generates waste. This assumption, although not very realistic, is made because the focus is on policies affecting the generation of waste by the households and not the generation of waste by the production sectors. The total costs of waste collection and treatment are quite small in comparison with the rest of the economy. Policies directly aimed at influencing total waste generations will have small effects on the total economy but can however have a large effect on the waste market.

Table 2 Substitution elasticities production sectors

	Agri	Indu	Serv	Extr	Rm	Rec	Col	Incin	Land	
elas1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	substitution elasticity between capital and labor
elas2	0.0	0.0	0.0							substitution elasticity between primary and intermediate inputs
elas3	1.0	1.0	1.0							substitution elasticity between materials and other intermediate inputs
elas4		∞								substitution elasticity between recycled material and virgin material
elas5							0.0			substitution elasticity between primary factors and waste treatment services
elas6							0.25			substitution elasticity between landfilling and incineration

All production sectors are characterized by a CES production function. Substitution elasticities for the different sectors are given in Table 2. Every producer uses the primary production factors capital and labor. The three production sectors of consumer goods (agriculture, industry and services) also use intermediate inputs for production. The use of primary factors and intermediate inputs is strictly complementary. Only the producer "industry" uses recycled material. Recycled materials and virgin materials can be fully substituted.

Table 3 Parameters households

	Priv	Govt	
elas1	1.0		substitution elasticity between consumer goods
elas2	0.0		Substitution elasticity between consumer goods and waste-collection / recycling
elas3	1.0		Substitution elasticity between recycling and waste collection
α	96.9	3.1	Negishi weights

The utility function of the private households is characterized by a CES function. The substitution parameters for the households are shown in Table 3. Utility of the private households depend both on consumption of consumer goods: agriculture, industry and services and waste treatment services: recycling and collection. Between consumer goods there is a substitution elasticity of 1 (Cobb-Douglas utility function). The substitution between consumer goods and waste treatment services is equal to 0. That means that these goods and services are completely complementary. Households have some substitution possibilities between the two waste treatment options recycling and waste collection. Utility of the government only depends on the consumption of services so no substitution elasticities have to be defined for the government.

The initial Negishi weights are determined on the basis of the initial income (sale of endowments). Since the income of the private households is far larger than the government income, the Negishi weight of the private households is far larger.

In the base case scenario about 12.5 million tons of waste is generated by the private households. The total percentage of waste generation as a function of consumption is equal to 0.69%. Of the waste generated about 20% is recycled and 80% is collected for waste treatment (either landfilling or incineration). Most of the waste collected is incinerated (75%). The rest is landfilled. The private households pay 9.5 million guilders in the form of a flat fee for collection of waste. This is lower than the real cost of waste collection, which equals 10 million guilders.

4.2 Different scenarios

The model specified above is used to analyze the effects different policy options have on the generation of waste and the cost of waste treatment. One of these policy options will be the change of a variable pricing scheme instead of the flat fee scheme for waste collection. This not an unrealistic policy scenario. Some municipalities in the Netherlands, especially smaller ones, are experimenting with introducing some sort of variable or semi-variable price scheme for waste collection. Three different scenario will be distinguished.

In the first simulation, a policy to promote recycling is introduced. This results in far lower production costs for recycling (production costs for recycling are halved) and thus a lower price for recycling services (the price of recycling costs is halved). The flat pricing scheme is not changed. This policy is labeled “pro-recycling scenario”.

In the second simulation the flat pricing scheme is replaced by a variable pricing scheme. This means that consumers will pay more money for collection of waste since the flat fee for waste collection is lower then the actual cost of waste collection. This policy is labeled “variable price scenario”.

In the third scenario both the variable pricing scheme and the lower recycling cost scheme are introduced. Comparing this scenario with scenario 1 will show how the effectiveness of the lower recycling cost scheme is affected by the flat fee scheme. This scenario is labeled “variable price and pro-recycling scenario”.

All policy scenarios are compared to the base case scenario. The base case scenario is described by the data presented in paragraph 4.1 without added policies.

4.3 Results

4.3.1 Pro-recycling scenario

In the first policy option, the production costs of recycling are lowered. This can be done by introducing an new technology parameter in the production set, which makes it possible to produce the same amount of units with the use of less production factors. In a flexible pricing system, this would lead to substitution from waste collection towards recycling. However, given the zero marginal costs for waste generation, the direct effect on recycling should be zero (there is still room for indirect effects as all quantities change).

Table 4 Changes in main variables “pro-recycling scenario”

	percentage change
Private consumption agricultural goods	0.014%
Private consumption industrial goods	0.019%
Private consumption services	0.020%
Government consumption services	0.013%
Recycling	0.020%
Waste-collection	0.020%
Utility private household	0.019%
Utility government	0.013%

Table 4 shows the changes in the most important variables. As could be expected, the change in most variables is virtually zero. Since the amount of recycling by the households was quite small in the benchmark data, the effects of lower recycling costs will be quite small. As expected, the ratio between recycling and waste collection for the households does not change. Both recycling and waste collection rises slightly with 0.020%. The absolute amount of recycling rises slightly because the consumer can consume more goods since it has to spend less income on recycling.

The utility of the private consumers rises slightly because lower recycling costs means a larger percentage of the income can be spend on consumer goods. The money the government spends on the subsidy is slightly increases since the consumers demand more waste collection services, this means that the government can spend less on consumption of services. However the utility of the government still slightly increases. This is due to a small decrease in the price of services, which means that the government can still consume more services although they have less money to spend on consumption goods.

4.3.2 Variable price scenario

In the second scenario, variable prices for waste collection are introduced. Households now pay the equilibrium price for waste collection and more generation of waste means more costs for waste collection.

Table 5 Changes main variables "variable price scenario"

	percentage change
Private consumption agricultural goods	0.000%
Private consumption industrial goods	0.000%
Private consumption services	-0.011%
Government consumption services	0.249%
Recycling	0.000%
Waste-collection	0.000%
Utility private household	-0.011%
Utility government	0.249%

The results of this scenario are shown in Table 5. Since the government does not have to bear part of the costs of collection anymore, consumption of the government and thus utility of the government rises slightly. Private households, now, bear the full cost of waste collection so their consumption and utility decrease slightly. There is no change in the amount of waste generated, only the costs of waste collection and treatment is divided differently over the two consumers..

4.3.3 Variable price and pro-recycling scenario

In the third scenario both the variable costs for waste collection and the lower price for recycling services are introduced simultaneously.

Table 6 Changes main variables "free price and pro-recycling scenario"

	Percentage change
Private consumption agricultural goods	-0.178%
Private consumption industrial goods	-0.002%
Private consumption services	0.026%
Government consumption services	0.256%
Recycling	0.101%
Waste-collection	-0.001%
Utility private household	0.009%
Utility government	0.257%

There is now a price incentive for the consumer to recycle more and to let less waste be collected by the municipality. This can be seen in Table 6. There is a slight increase in recycling and a very slight decrease in demand for collection services. Due to the lower costs for waste treatment, consumption and utility of the private households increases slightly. Compared to the results of scenario 2 there is now a small increase in utility of the consumer in stead of a decrease of utility.

Scenario one and scenario three show the effectiveness of policies aimed at promoting recycling under different pricing schemes for waste treatment. Under the fixed fee pricing scheme, promoting recycling is not very effective. Although recycling increases somewhat, this is only caused by the increased relative income of the consumer. Consumption rises, waste generation rises and waste collection rises; the exact opposite of the goal of the policy change.

In scenario three however, the amount of waste generated goes down. More waste is recycled and less waste is collected. Comparing these scenarios show that in the case of a flat fee for waste collection, the market is distorted and the price of recycling has no impact on the behavior of households.

5 Discussion

In this article we have demonstrated how a simple model of the waste market can be modeled by use the applied general equilibrium theory. Since one of the characteristics of the waste market is the flat fee pricing scheme for waste collection, it is important to realize that the actual price for waste collection that the consumers perceive is equal to zero. Special attention, therefore, has been given to modeling goods with a zero price. Introducing such a market distortion has strong effects on the results of the model. This was shown in the application of the model in a numerical example.

The results show that the introduction of a flat fee for waste collection takes away the incentive for recycling. As long as there is a flat fee, the private households do not have an incentive to reduce their waste and will not recycle anymore. Making recycling more attractive by reducing the costs of recycling, will not result in less generation of waste. On the contrary, less recycling cost results in more waste being generated, due to the income effects of lower recycling costs. Only when policies promoting recycling are combined with a variable pricing scheme for waste collection will these policies be effective.

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Appendix A: Solving a Negishi format

The Negishi model calculates the equilibrium through an iterative process. First the equilibrium is determined by solving the maximization model

$$TW = Max \sum_i \alpha_i u_i(x_i, r_i, w_i) \qquad \textbf{(A.1)}$$

Subject to the balance constraint:

$$\sum_i \sum_g x_i^g + \sum_i r_i + \sum_i w_i \le \sum_i \omega_i + \sum_j y_j, \qquad \perp p \qquad \textbf{(A.2)}$$

The Negishi weight are initialized as follows:

$$\alpha_i = \frac{h_i}{\sum_i h_i} \qquad \textbf{(A.3)}$$

This means that the Negishi weight of consumer *i* is determined by the initial share this consumer has in total income. If the share of consumer *i* in the total income is large, the Negishi weight of the consumer will be large and vice versa. It is assumed that the utility function of both consumers are homothetic and commodity endowments are strictly proportional. Homothesticity ensures that the composition of

a utility maximizing commodity is unaffected by the level of income. As income levels are varied, while relative prices remain fixed, demand quantities all change in fixed proportion (i.e. the Engel curves are straight lines from the origin). The individual utility functions are homogenous with respect to the amount of goods. Because of this assumption, the social demand, i.e. the sum of individual demands, is proportional to the level of the total income, independent of its distribution and so the competitive equilibrium prices and therefore the resultant allocation of resources is independent of income distribution and the problem of income distribution is assumed away (Negishi, 1972).
After the model is solved, the shadow price of each commodity is calculated. Then these shadow prices are used to calculate the income deficit of each consumer (i.e. the difference between total income and total expenditure of each consumer, labeled 'loss').

$$loss_i = p\omega_i - \sum_i px_i^g + pr_i + pw_i \qquad \textbf{(A.4)}$$

If the loss for each consumer is equal to zero then the equilibrium solution is found. If the loss is not equal to zero then the Negishi weights are adjusted:

$$\alpha_i = \alpha_i + \beta \frac{loss_i}{\sum_i h_i} \qquad \textbf{(A.5)}$$

So if a consumer has surplus (i.e. income is larger then expenditure) then the Negishi weight will become larger. In the next iteration, consumption by this consumer will be larger due to the larger Negishi weight. This iterative procedure will result in a set of unique equilibrium Negishi weights and prices.