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# Socio-economic aspects of the greenhouse effect: Applied general equilibrium model

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*Abstract*

To assess the economic consequences of environmental taxation a general equilibrium model is applied. The model contains 60 firm sectors and 44 household groups, which makes it especially suitable to analyse the sectoral and distributional effects of environmental taxes. These sectoral effects are rather large and diverse in comparison to the macro-economic consequences. After a short overview of the relevant literature, the original model and the model adaptations are described. These model adaptations include an iterative procedure to avoid substantial linearisation errors when large impulses are simulated. Possible model simulations are identified and the working programme is presented.

## 1. Introduction

The economic models of the Central Planning Bureau have been used to estimate effects of a $CO_2$ charge. The CPB models yield macro-economic consequences, but are not sufficiently capable to analyse distributional consequences. Disaggregated general equilibrium models, assuming an optimizing behaviour of the target groups, are better suited to analyse the long term tax incidence. In this sense, an applied general equilibrium model is complementary to the CPB models. In this project (NOP 851061E), the so-called Keller model is being modified and applied to assess the sectoral economic consequences of a energy/$CO_2$-tax on both firms and households.

## 2. Overview of the literature

The literature on the economic consequences of environmental taxation may be divided into two categories. First, there is a theoretical approach, which uses analytical general equilibrium models to analyse the effects of increased environmental concern on macro-economic variables like production growth, employment and environmental quality in a second-best framework. If labour is immobile and goods, capital and natural resources can be freely traded, the burden of the environmental tax is transfered completely to labour, and is thus an *implicit* labour tax, which is less efficient than an *explicit* labour tax. Consequently, employment declines and environmental quality improves mainly due to lower production. If on the contrary capital is the fixed input and involuntary employment exists at fixed wages, the fixed factor bears part of the burden of the environmental tax. In this case, employment may rise in combination with higher environmental quality (see Bovenberg and van der Ploeg, 1993). In addition, Bovenberg and de Mooij (1993) argue that part of the burden of an environmental tax in combination with lower labour taxes may be transferred to non-labour income, thereby decreasing unemployment at the cost of greater inequality in income distribution.

Secondly, there are several empirical models. These models can be sub-divided into three different approaches. The first sub-category, the aggregated general equilibrium long-term world models, is the focus of an other NOP-project carried out at the IVM (The Climate Fund, see Tol, 1993) and will not be discussed here. A second sub-category are the applied general equilibrium models (*e.g* Jorgenson and Wilcoxen, 1993; OECD, 1994). These models show on average an slightly negative effect of environmental taxation on the economy. A last sub-category that can be identified contains the macro-economic disequilibrium models. The Dutch Central Planning Bureau used a macro-econometric model to investigate the economic consequences of regulating energy levies (CPB, 1992). Their results are rather negative: large economic damage with relatively small environmental benefit. This results hinges on the (exogenous) movement of industries outside the taxed area. Other macro-economic studies, like the HERMES-study for the European Union (e.g. European Commission, 1993) don't take industry-movements into account and find slightly positive results for both production growth and employment.

## 3. The original model

The original Keller model is a comparative static general equilibrium model, which distinguishes between different production sectors and different household groups. It is based on optimising behaviour of the target groups, for whom demand equations are specified. The public sector is sub-divided into three sectors, *i.e.* a household sector for public consumption, the public services firm and a so-called "fisc" to deal with all tax payments. One of the household sectors in the model is called "rest of the world", including all international transactions (see Keller, 1980). Capital may be specified as mobile or immobile. Furthermore, households may be rationed (see Cornielje, 1990).

For every good a market exists in which the price mechanism ensures that demand is equal to supply. There are three types of goods in the model. First, there are the primary inputs, which are provided by the households (including the public sector and rest of the world). These primary inputs, *a.o.* labour services and net imports, are demanded by firms. Firms provide the other two types of goods, intermediate goods and final output. These two types of goods only differ with respect to the consuming sector: intermediate goods are demanded by firms and final output is demanded by the households.

The original purpose of the model is to analyse the incidence of small changes in the taxing structure. The equations in the model are marginal and linear. This means that the marginal behaviour of the agents is specified, using a locally defined linear approximation of the underlying global non-linear micro-economic relations.

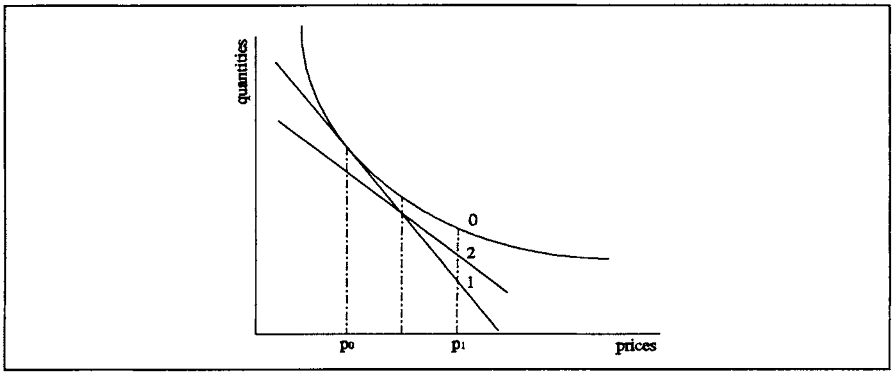
## 4. An updating procedure

As said before, the original model is only locally defined, since the equations are linear approximations of global non-linear relations. The results of simulations wth the linear model therefor only hold exactly for infinitesimally small impulses. However, environmental taxes are likely to be of substantial magnitude. The results thus obtained are biased, or in other words, a linearisation error is made.

To reduce this linearisation error a specific updating procedure is required. The large total tax impulse is broken down into several small steps and the consumer and producer elasticities are re-evaluated after each step. In this way, the advantages of the linear model are retained, while the re-evaluation of the parameters on basis of the global non-linear model reduces the linearisation error substantially (see Bovenberg and Keller, 1984 for technical details).

The graph shows an example where the linearisation error is brought down from 0-1 to 0-2 when a two-step procedure is applied (*i.e.* one update).

Figure 1. Linearisation errors in a demand equation




## 5. Data adaptations

The original data set which was available needed adaptations on several points. First, the old data set was for 1981. Unfortunately the most recent disaggregated household data available at this moment are on 1988, so a full new dataset for 1988 has been constructed. Energy inputs for both households and firms were disaggregated, to allow for more detailed analysis of the economic consequences of energy and $CO_2$ levies. The new dataset contains 60 firms, 44 private households, 88 intermediate goods and 7 primary inputs.

The input-output table has been transformed into so-called total accounts, *i.e.* a sector times sector matrix. As said before, each firm uses primary inputs and intermediate goods to produce one and only one homogeneous output. In an analogous manner household data (including the public sector and rest of the world) are transformed from a 46 x 95 matrix into a 46 x 67 total account.

## 6. Model simulations

The (adapted) model is capable of analysing various simulation alternatives. Besides the usual choices concerning height of the tax (*e.g.* 50 percent), base of the tax (based on energy-content vs. based on $CO_2$-content) and destiny of the tax (*e.g.* lower VAT, lower labour taxes, an international fund, etcetera), our sectoral model can cope with differential taxes, where some energy-users are faced with lower or no environmental taxes (tax exemption for energy-intensive export-oriented industries is the most likely example). Furthermore, the model is capable of analysing the effects of specific policies, like an abolishment of energy price differentiation between sectors.

In coordination with the State University of Groningen, possible simulations on tradeable emissions permits will be identified.

## 7. Working programme

In the next months the proposed simulations will be run with the new calibrated model. We expect that these simulations will show the diverse and large sectoral effects of environmental taxes, which are are not reflected in the traditional policy-oriented macro-economic models. The final report will be completed Spring 1995.

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