Economic Instruments and the Kyoto Protocol: Environmental Taxes versus Tradable Pollution Permits.

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Summary

The Kyoto Protocol was accepted by the European Commission in April 2002, laying down a distribution system of emission reduction efforts among the member countries in order to reach the objective of 8% for the entire EU. Among the measures adopted by the EU for the fulfilment of the Protocol, there is a Directive (2003/87/CE) establishing a scheme for carbon dioxide emission allowance trading within the Community. The sphere of application to the market is limited, so only certain sectors will be regulated by this measure. This fact has important consequences in terms of efficiency costs and distributional effects among sectors. In this paper, we use a static general equilibrium model to assess the effects of this new environmental policy in Spain. The paper also compares the restricted market with broader instruments by including all sectors. The results obtained show that the costs of reaching the objects set by the EU for Spain are of little significance. We show also the efficiency costs raised by the narrow nature of the European market. Finally it corroborates the fears expressed by industrial sectors against carbon taxes as they raise revenues whatever is the level of emissions.

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1. Introduction

The Kyoto Protocol was accepted by the European Commission in April 2002, laying down a distribution system of emission reduction efforts among the member countries in order to reach the objective of 8% for the entire EU. Among the measures adopted by the EU for the fulfilment of the Protocol, there is a Directive (2003/87/CE) establishing a scheme for carbon dioxide emission allowance trading within the Community. This gas is the main cause of global warming, representing around 80% of total greenhouse gas precursors.

The market sphere of application is limited, so only certain sectors will be regulated by this measure (electric generation, refinement of petroleum, the industries of iron and steel, cement, lime, glass, ceramics, brick and tile, paper and paper pulp). The binding sectors by the Directive represent about 40% of total CO_2 emissions in the EU. The rationale for such a limited market has to be found mainly in two reasons. On the one hand, polluters like households or small firms must incur in high transaction costs (information about market operation, loss of time, etc) which outweighs any environmental benefit. On the other hand, the exorbitant administrative and monitoring costs for the government (inspectors, emission meters, etc) to enforce the environmental regulation by small polluters do not pass a cost benefit analysis.

The European market for pollution permits will come into force in the year 2005. Pollution permits will be freely allocated (grandfathering) among sectors. This is despite some emerging empirical evidence (Parry et al. 1999; Fullerton and Metcalf 2001) concluding that auctioning is the best cost-effective way to allocate permits when raised revenue is recycled to reduce distorting taxes, as opposed to grandfathering. That choice by the European Commission reflects the aim to avoid past political resistance in each EU member country as a consequence of lobbying activities by regulated firms[1]. Industrial sectors typically reject revenue raising instruments because they directly increase their costs and prefer instruments that raise scarcity rents to existing firms (pollution permits than can be sold) which introduces important distributional consequences among sectors.

[1] European Commission proposals for an energy-carbon tax was looked in the nineties because of fears to competitiveness losses in some countries.

Each EU member country and not the European Commission must design the national plans for the allocation of rights among the different sectors. The necessity for additional measures is also established along with their basic principles to assure monitoring of sectors not included in the market, since they generate more than 50% of the CO_2 emissions. Such measures are oriented toward policies of energy saving and energy efficiency, although this does not rule out the use of environmental taxes by each country.

With respect to the situation in Spain, the economic growth of recent years together with the lack of political initiatives has led Spain through a path of strong growth in the consumption of energy. At the end of 2002, Spain's emissions of greenhouse gases had grown approximately 40% and represent about ten percent points of EU emissions in absolute terms. This represents an unsustainable performance from an environmental point of view. Furthermore this figure correspond to almost 25 percentage points of excess over the maximum limit allocated for Spain by the EU. This situation leads Spain to an inconvenient political position since the distribution of emissions within the EU was beneficial in permitting to increase Spanish emissions up to a maximum of 15% in the period of 2008-2012. This is true also from an economic point of view as Spain risks paying important sanctions to the European Commission.

There are three important emerging consecuences from the environmental policy designed by the European Commission. On the one hand, it represents an inefficient regulation of CO_2 emissions because emitters that acccount for as much as 60% of them are excluded from the pollution market. On the second hand, it would be more expensive to attain any environmental objective because the market will leave aside emitters with low abatment costs. And finally, it neglects the benefits from the recycling effect of revenue raising instruments. Rents captured by firms with grandfathering allocation of permits could be socialized and employed to reduce pre-existing distorting taxes (Boemare and Quirion, 2002).

The objective of this work is twofold. On the one hand, to analyse the costs for Spain of fulfilling the European Community objectives of reducing emissions. This is the main contribution of the paper representing the first attempt to our knowledge in the Spanish empirical literature. On the second hand, to show the efficiency and distributional costs from the limited scope for such a market. To this end we simulate different frameworks for a market of CO_2 pollution permits in Spain.

The methodology employed is a static applied general equilibrium model for a small open economy. The consumption of energetic assets on the part of industries and institutions has been broken down as much as possible from the national accounting data supplied. This characteristic lends the model sufficient flexibility so that the agents may substitute, in an efficient manner, the consumption of some energy assets for others that are less pollutant. In addition, the model simulates the CO_2 emissions associated with the consumption of fossil fuels. Both characteristics permit the model to minimize the costs of the environmental policy.

We simulate the market for CO_2 pollution permits as it is contained in the Spanish National Plan against green house gases and it is to be launched in 2005. The results obtained show that the costs of reaching the objects set by the EU for Spain are of little significance. Additionally we simulated the same market but including all producers in the economy. The costs for the economy of this broader nature of the market for the same environmental objectives are lower than in the previous scenario as expected. Therefore there are some efficiency costs from the narrow nature of the market to be launched in 2005.

Finally we compare the last scenario, grandfathering allocation of permits between all producers in the economy, with a hypothetical policy where permits are auctioned among sectors in a way that resembles a carbon tax. We concluded that grandfathering allocation of permits ensures a better performance of the Spanish economy as compared to auctioned permits when revenues are given back to the households through lump sum transfers (no revenue recycling process).

Therefore, the conclusions obtained from the available empirical evidence are clear. It is especially advisable to introduce, as soon as possible, public measures for the control of Spanish greenhouse gas emissions. Obviously, these should be introduced through cost-effective instruments like a market of pollution permits that should include all emitters in the economy. However either transanction and monitoring costs as well as political concerns prevents the regulator from introducing such measures. A hybrid system of taxes on some sectors and institutions along with an emission commerce system for some specific industrial sectors as the European could be used in order to prevent these problems. This does not represent a new claim. Thus, McKibbin and Wilcoxen (1997) and Pizer (1997) defend the use of tradable pollution permits assigned for free by the government among the different sectors, together with additional permits at a price set beforehand by the government (equivalent to an environmental tax). The Spanish National Plan against greenhouse gas emissions already takes into account this possibility.

This article is structured into four sections, including this introduction. In section 2, the methodological approach is characterized, with a description of the theoretical model and the empirical implementation. Section 3 presents the policies considered and the results obtained from those simulations. Finally, section 4 includes the main conclusions of the article and some policy implications.

2. The computable general equilibrium model

The methodology utilized is a static applied general equilibrium model[2]. The breakdown of the energetic sectors in the model, and the environmental model, permit us to analyse both the effects on efficiency and on the environment. We likewise to include the conclusions of different papers as Dean and Hoeller (1992), Grubb et al. (1993), Clark, Boero and Winters (1996), Repetto and Austin (1997), Hawellek, Kemfert and Kremers (2004). They highlight the importance of breaking down the energy assets in the economy so as not to produce biased estimation of the costs of environmental policies. Our treatment of energy assets and emissions follows a methodology similar to that used in other models such as GTAP-E (Rutherford and Paltsev, 2000) or MGS-6 for Norway (Faehn and Holmoy, 2003).

Our analysis of the effects of fulfilling the Kyoto Protocol in Spain is especially relevant owing to the scarce empirical evidence available. There only exist two works that are applied specifically to Spain that analyse the effects of different policies against climate change, using a static general equilibrium model. Manresa and Sancho (2004) study the possible existence of double dividends of "green" fiscal

[2] This is basically the same model as in Labandeira et al (2004).

reform in Spain. Unfortunately, the approach used is not satisfactory because of the lack of substitution possibilities between energy goods and value added in the production function. Moreover they are incapable of simulating the CO_2 emissions produced by the consumption of fossil fuels and the volume of emissions are a function of the level of production in each sector. Therefore, the policies simulated consider homogenous, ad-hoc increases in the indirect taxation on energy assets, and are incapable of generating the substitution effects for a real environmental tax. There also exists an unpublished work by Gómez and Kverndokk (2002) in which the authors also analyse the effects of a "green" fiscal reform in Spain. In this case, the authors simulate the CO_2 emissions directly associated with the consumption of different fossil fuels. Some works applied to the EU also include results for Spain, such as those of Carraro, Galeotti and Gallo (1996), Capros et al. (1995), Bohringer, Ferris and Rutherford (1997), Barbiker et al (2001), and Barker and Köhker (1998).

2.1 Model

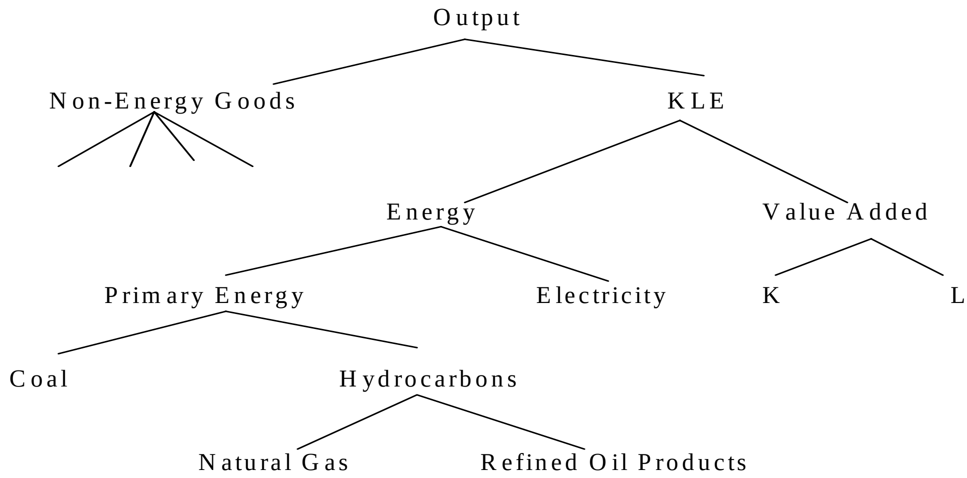
To evaluate the efficiency effects of environmental and energy policies, we use a multi-sectorial static applied general equilibrium (AGE) model for an open and small economy such as Spain. This kind of model allows a greater breakdown of institutions and sectors. This is an important feature of the model in order to take into account the heterogeneity of energy consumption between sectors. That allows us to break down the energy sector as much as possible. Therefore the AGE can take into account, to some extent, the different services provided by energies (intermediate inputs for production of electricity; lighting, heating and transport services for firms and institutions, etc) and differences in CO_2 emission factors.

There are 17 productive sectors in the economy and therefore 17 commodities. Industries are modeled through a representative firm. They minimize costs subjected to null benefits at the equilibrium. Output prices are equal to average production costs, as we assume perfect competition and constant returns to scale. The production function is a succession of nested constant elasticity of substitution (CES) functions, as illustrated in Figure 1[3]. The energy goods are taken out from the set of intermediate inputs. They are included in a lower nest within the

[3] The appendix contains a detailed description of sectors and elasticities of substitution.

production function, allowing for more flexibility and substitution possibilities (from dirtier to cleaner energies on the basis of emission factors). Therefore our model is similar, although with some changes, to that used by Böhringer, Ferris and Rutherford (1997).

Figure 1. Production technology structure chain



As usual in AGE models[4], total production in sector i, measured in units and indicated by B_i, is a combination through a Leontief function of intermediate CID_{ji} inputs and a composite good made up of capital, labour and different energies, KEL[5]. Where c_0 and c_{ij} are the technical coefficients measuring the minimum amount of each input to produce one unit of output in

$$B_i = \min\left(\frac{KEL_i}{c_{0i}}, \frac{CID_{1i}}{c_{1i}}, \ldots, \frac{CID_{ni}}{c_{ni}}\right) \tag{1}$$

In a lower nest, capital and labour are combined according to a CES function to produce the value added consumed by industries[6]. In a similar way, electricity, coal, gas and refined oil products are combined at different stages of the chained structure of the production function to produce the composite energy input as

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[4] See Shoven and Whalley (1992).

[5] As a general criterion, the notation used follows the following convention. The endogenous variables are written in capital letters. The exogenous variables are written in capital letters with a line on top. There are 17 productive sectors (*i,j=1, ..., 17*) and, consequently, 17 consumer commodities.

[6] See the appendix for more details about the production function.

illustrated by Figure 1. Finally, value added and energy are combined with a CES function, as in (2). Where α is a scale parameter, σ_i^{KEL} is the elasticity of substitution and a_i is the share of value added (*KL*) in the nest.

$$KEL_i = \alpha_i \left(a_i KL_i^{\frac{\sigma_i^{KEL}-1}{\sigma_i^{KEL}}} + (1-a_i) E_i^{\frac{\sigma_i^{KEL}-1}{\sigma_i^{KEL}}} \right)^{\frac{\sigma_i^{KEL}}{\sigma_i^{KEL}-1}} \tag{2}$$

We follow the Armington approach to model the international trade of goods as usual in the literature (Shoven and Whalley, 1992). Imported products are imperfect substitutes for national production. Therefore, the total supply of goods and services in the economy A_i is a combination of domestic production B_i and imports from different origins IMP_i with a CES function, as in equation (3). Where λ_i is a scale parameter, σ_i^A is the elasticity of substitution and b is the share of domestic production in total supply of sector i,

$$A_i = \lambda_i \left(b_i B_i^{\frac{\sigma_i^{A}-1}{\sigma_i^{A}}} + (1-b_i) IMP_i^{\frac{\sigma_i^{A}-1}{\sigma_i^{A}}} \right)^{\frac{\sigma_i^{A}}{\sigma_i^{A}-1}} \tag{3}$$

Maximization of benefits by each sector, determined via a constant elasticity of transformation (CET) function[7], allocates the supply of goods and services between the export market EXP_i and domestic consumption D_i. Where γ_i is a scale parameter, σ_i^{ε} is the elasticity of transformation and d_i is the share of domestic consumption. Since the Spanish economy is small and most commodity trade is made with EMU countries, there is no exchange rate (it is fixed) and all agents face exogenous world prices[8],

$$A_i = \gamma_i \left(d_i D_i^{\frac{\sigma_i^{\varepsilon}+1}{\sigma_i^{\varepsilon}}} + (1-d_i) EXP_i^{\frac{\sigma_i^{\varepsilon}+1}{\sigma_i^{\varepsilon}}} \right)^{\frac{\sigma_i^{\varepsilon}}{\sigma_i^{\varepsilon}+1}} \tag{4}$$

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[7] See Shoven and Whalley (1992) for a description on how international commerce is treated in AGE models.

[8] We assume that the policy simulated has no significative impact on the Euro exchange rate as Spain's major business partners are countries which belong to the European Monetary Union (EMU).

Capital supply is inelastic (exogenously distributed between institutions), perfectly mobile between sectors, but immobile internationally. The model assumes a competitive labour market and therefore an economy without involuntary unemployment. The labour supply made by households to maximize utility is also perfectly mobile between sectors but immobile internationally.

Following the breakdown of Spanish national accounts, there are five institutions in the economy[9]: a representative household, a public sector, a foreign sector, non-profit household-serving institutions (NPHSIs)[10] and corporations. In general, they receive capital income, carry out net transfers with other institutions and make savings in order to balance their budget[11]. NPISHs consume commodities and services determined via a Cobb-Douglas function subject to their budget constraint and their savings are proportional to their consumption of goods and services. The public sector collects direct taxes (income taxes from households, and wage taxes from households and sectors) and indirect taxes (from production and consumption). Endowment of capital for the government (K_G), transfers with other institutions (TR_G) and public deficit (DP) are exogenous variables. The consumption of goods and services (D_{iG}) by the government is determined by a Cobb-Douglas function, where PD_i stands for domestic prices. Therefore, total public expenditure, capital income (where r is the price for capital services) and tax revenues (REV) have to be balanced in order to satisfy the budget restriction,

$$\overline{DP} = r \cdot \overline{K}_G + \overline{TR}_G + REV - \sum_{i=1}^{17} PD_i \cdot D_{Gi} \qquad (5)$$

The representative household has a fixed endowment of time (TIME) which allocates between leisure (LS) and labour. It maximizes utility (W), which is a function of leisure (LS) and a composite good (UA) made up by goods and savings, subject to the budget constraint[12].

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9 These are the institutions in the new European System of Accounts (ESA-95). AGE models with a similar set of institutions can be found in Lofgren, Harris and Robinson (2001) and Naastepad (2002).

10 NPISHs consist of non-profit institutions that are not predominantly financed and controlled by the government. Some examples of NPISHs are professional associations, social clubs, charity organizations, etc.

11 Capital endowments and transfers are exogenously determined.

12 σ^{UB} is the elasticity of substitution and s_{UB} is the share parameter for leisure on welfare.

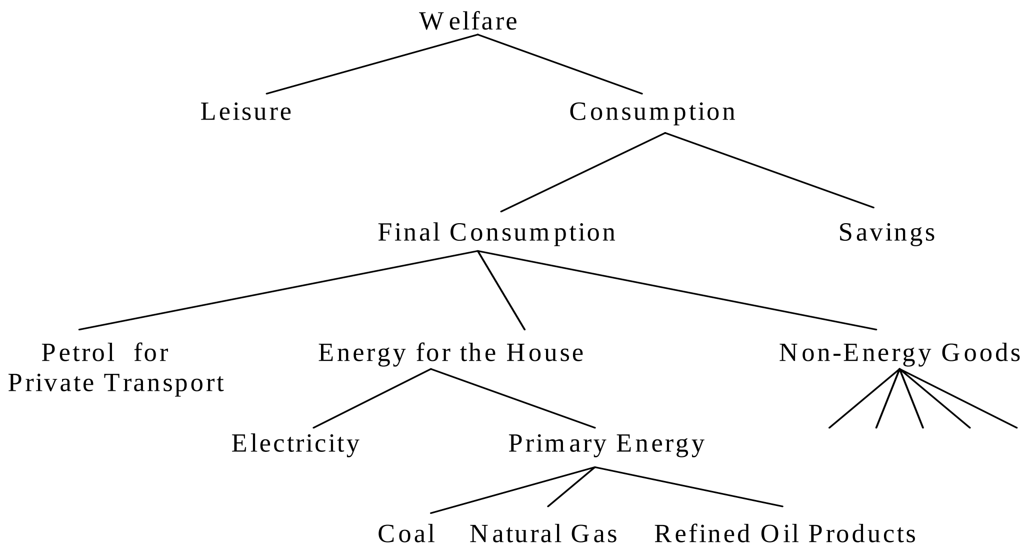
$$W = \left(s_{UB} LS^{\frac{\sigma^{UB}-1}{\sigma^{UB}}} + (1 - s_{UB}) UA^{\frac{\sigma^{UB}-1}{\sigma^{UB}}} \right)^{\frac{\sigma^{UB}}{\sigma^{UB}-1}} \tag{6}$$

It is assumed, as in Böhringer and Rutherford (1997), that consumers have a constant marginal propensity to save, which is a function of disposable income (Y_H). The latter is equal to the sum of capital income, plus labour income (w is the nominal wage and SC_H stands for social contributions, or labour taxes), plus transfers (TR), minus income taxes (T_H is the tax rate),

$$Y_H = (1 - T_H)\left[r \cdot \overline{K}_H + w(1 - SC_H) \cdot (\overline{TIME} - LS) + \overline{TR}_H \right] \tag{7}$$

Consumption of goods and services is defined by a nested CES function, as shown in Figure 2, with special attention being paid to the consumption of energy goods. An important contribution of the AGE model is the distinction between energy for the house, energy for private transport and other products. Other non-energy goods are a composite good formulated via a Cobb-Douglas function.

Figure 2. Chained household consumption function structure



The AGE model represents a structural model based on the Walrasian concept of equilibrium. Therefore, for each simulated policy, the model must find a set of prices and quantities in order to clear up all markets (capital[13], labour and commodities). Total savings (*SAVINGS*) in the economy is defined endogenously, and is equal to the sum of savings made by each one of the institutions. The macroeconomic equilibrium of the model is determined by the exogenous financing capacity/need of the economy with the foreign sector (*CAPNEC*). That is the difference between national savings, public deficit and national investment. The latter is a composite good made up by a Leontief function regarding the different commodities used in gross capital formation (INV_i),

$$SAVINGS + \overline{DP} - \sum_{i=1}^{17} PD_i \cdot INV_i = \overline{CAPNEC} \qquad (8)$$

International prices PXM_i, transfers between the foreign sector and other institutions and the consumption of goods and services in Spain made by foreigners D_{iRM} are exogenous variables. Therefore exports EXP_i and imports IMP_i have to be balanced in order to satisfy the restriction faced by the foreign sector,

$$\sum_{i=1}^{17} \overline{PXM}_i \cdot EXP_i + \overline{TR}_{RM} + CNR - \sum_{i=1}^{17} \overline{PXM}_i \cdot IMP_i = \overline{CAPNEC} \quad \text{where} \quad CNR = \sum_{i=1}^{17} PD_i \cdot \overline{D}_{iRM} \qquad (9)$$

The model simulates energy-specific CO_2 emissions produced by different sectors and institutions. Therefore, we do not simulate the emissions made by some industrial production processes such as cement, chemical, etc. They only represent about 7% of total Spanish CO_2 emissions in 1995 (INE, 2002b).

Emissions are generated during the combustion processes of fossil fuels only. Therefore, there is a technological relationship between the consumption of fossil fuels in physical units and emissions (θ_C , θ_R and θ_G; for coal, refined oil products and natural gas respectively). For example, CO_2 emissions from sector i are calculated as follows:

$$CO2_i = \theta_{Ci} \cdot COAL_i + \theta_{Ri} \cdot REF_i + \theta_{Gi} \cdot GAS_i \qquad (10)$$

[13] There is no quantity adjustment in total supply of capital in the economy, only between sectors, because capital endowment is an exogenous variable. The equilibrium condition is attained through changes in the price of capital services (*r*).

where *REF* stands for refined oil products.

2.2. Data and calibration

The model database is a national accounting matrix for the Spanish economy (NAM-95), erected on the basis of the national accounts for 1995[14], following the European System of Accounts (ESA-95). Furthermore, we have extended the database with environmental data from different statistical sources (INE, 2002b; IEA, 1998) relating consumption of different fossil fuels and emissions for each sector and institution. Based on the information obtained from the NAM-95, the model's parameters can be gauged by calibration: tax rates or technical coefficients for production, consumption and utility functions. The criterion to calibrate the model is that the AGE model replicates the information contained in the NAM-95 as an optimum equilibrium, which will be used as a benchmark[15]. Certain parameters, such as elasticities of substitution, have not been calibrated, but taken from pre-existing literature[16].

An important parameter in the model like the wage elasticity of the labour supply is equal to -0.4, similar to that estimated for Spain by Labeaga and Sanz (2001). In order to gauge the elasticity of labour supply, we have followed the procedure used in Ballard, Shoven and Whalley (1985) assuming, as in Parry, Williams and Goulder (1999), that leisure represents a third of the working hours effectively carried out in an initial equilibrium situation. We made a sensitivity analysis, increasing and reducing the labour elasticity by 50%. From this analysis we can conclude that results from the AGE are robust.

The database contains only monetary values from the national accounts, and therefore we can not distinguish between prices and quantities. As usual in this literature, we follow the Harberger convention to calibrate the model at the benchmark. As a result, all prices for goods and factors and activity levels are set equal to one, whereas the amount of consumption and production are set equal to

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[14] It is based on a NAM published by Fernandez and Manrique (2004) and the National Accounts (INE, 2002a). For a detailed description of the NAM-95 and the procedure used, see Rodríguez (2003).
[15] For a brief introduction to this methodology, see Shoven and Whalley (1992).
[16] Appendix contains a detailed description of subtitution elasticities used in the AGE.

the monetary values in the database. Following this convention, we can analyse the effects of simulated policies as relative changes in prices and activity levels with respect to the benchmark. The AGE model has been programmed in GAMS/MPSGE and we calibrated the model following the procedure in Rutherford (1999) by using the solver-algorithm PATH.

3. The costs of Kyoto for Spain

3.1. Simulated policies

In 2002, Spanish greenhouse gas emissions had grown approximately 40% with respect to emissions from 1990. The rough draft of the national plan for the allocation of emission rights, drawn up by the Spanish government in August 2004, establishes that between 2008 and 2012, the average amount of emissions should not go beyond the emissions made in 1990 by more than 24%. This value is the result of the sum of the maximum limit given by the EU for Spain (+15%), the estimation of the absorption of drains (-2%) and the credits coming from the foreign market (-7%). In the current situation (the best of the scenarios), it would be necessary, therefore, to reduce emissions by 16% in order to reach the growth of emissions equal to +24% established by the Spanish government.

According to the European Commission Directive (2003/87/CE) the sphere of application to the market is limited, so only certain sectors will be binding by a market of permits (electric generation, refinement of petroleum, the industries of iron and steel, cement, lime, glass, ceramics, brick and tile, paper and paper pulp). The CO_2 emission permits will be allocated free of charge (grandfathering) among sectors participating into the market[17].

In this paper we simulate several frameworks for the pollution market which will allows us to understand the insights of its implications and policy recommendations. Firstly we simulate the market for permits as it is contained in the Spanish National Plan against greenhouse gases by reducing allocated permits by a 16% in each sector. We call this scenario as the ***real market***. So we simulate

[17] There is a tiny fraction that could be auctioned but it does not represent a significant amount.

grandfathering allocation of permits between those sectors included in the Directive except paper and paper pulp. Unfortunately our data base does not allow us to disaggregate the chemical sector between different activities. However the lack for including the paper and paper pulp sector in our market should not have a significant impact in our results because CO_2 made by this sector represents only a small fraction of total emission in the economy (1,35%).

Secondly we simulate a broader versions of above market by including all sectors in the Spanish economy (households remain excluded of the market). We call this scenario as the ***wide market***. The purpose of this scenario is to analyse the efficiency costs of the narrow nature of the environmental design in the European Community Directive. This is clearly of interest when there exist a great number of small non-mobile emitters (e.g. small businesses and industries, or agricultural operations) or mobile ones (e.g. automobiles and trucks). Their inclusion in the emission permit market is not advisable for reasons of the high transaction costs that the polluters would be subject to, or the disproportionate costs of control and monitoring on the part of the regulator. However, sectors such as these represent more than 50% of the greenhouse gas emissions in developed countries. For instance, the transport sector, not subjected to the European emissions permit market, currently represents 24% of the total of Spanish greenhouse gases. Its emissions have grown by a 60% between 1990 and 2002. Therefore, there exist reasons of efficiency and fairness that cause this and other sectors excluded from the permit market to also be the object of cost-effective regulations.

Thirdly we simulate the broader market for all producers but now the permits will be auctioned by the government instead of being grandfathering. We call this scenario as the ***auctioned market***. The revenue raised will be given back to the economy by lump sum transfers to the households[18]. Lump sum transfers are restricted to keep public expenditure constant in real terms. Our election of this rebate measure is to supply a scenario that can be compared with the other two without introducing any other political consideration like double dividends. Under some theoretical conditions this scenario is equivalent to a tax on CO_2 emissions when the fiscal collections generated by the tax are returned to citizens through

[18] In preparing this work we simulated also an additional scenario where the revenues were devoted enterely to new public expenditures. The differences between results from this new scenario and the third one were not significant so we have not included details about this aditional simulation in the paper.

lump sum transfers. The reimbursement of the collections through lump sum transfers assures us that the only distortions in the efficiency generated by the simulated policy will be attributable to the market for permits, which is to say, the environmental objectives. To analyze the effects of different fiscal policies through "green" fiscal reforms and the existence or non-existence of double dividends (Bovenberg and Goulder, 2002) is therefore outside of the objectives proposed in the work.

In order to make a correct interpretation of results the number of permits issued by the government in the *wide* and *auctioned* markets is an endogenous variable subject to the constraint that both scenarios produce the same reduction on overall CO_2 emissions as in the *real market* scenario.

3.2. Results

Real Market

The market for permits as it is contained in the Spanish National Plan against greenhouse gases will decrease overall CO_2 emissions by a -5,63%. The costs of this plan for the economy are not significative as the gross domestic product (GDP) decreases only a 0,0645% with respect to the benchmark (at producer prices net of taxes). Free allocation of permits between sectors included in the Directive (grandfathering) will not have any effect on the remuneration of labour and capital (in real terms[19]) and the labour supply made by the households. The consumer price index will increase by only a 0,1%.

As a consequence of all these effects the welfare losses represent only a 0,047% of benchmark welfare level (measured as equivalent variations). This is a reasonable result if we take into account that the expenditure made by the households in energy goods represents on average less than a 10% of total expenditure. We can conclude therefore that the National Plan against green house gases will have not significative effects on welfare or the performance of the Spanish economy.

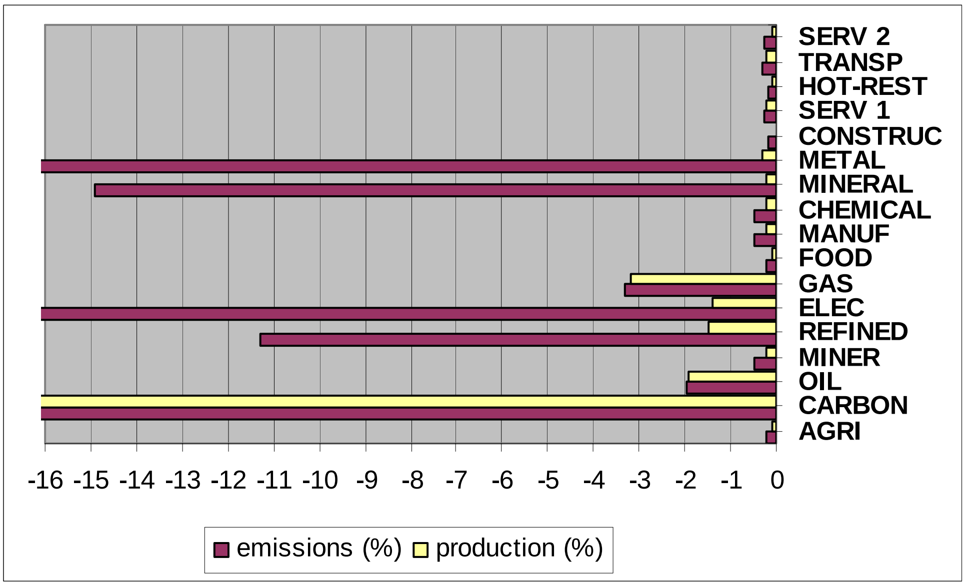
[19] Relative prices with respect to Consumer Price Index.

From the simulation of said policy, we can understand the effects on the level of activity and the emissions in different sectors of our model, which are shown in figure A. The most significant effects on production and emissions arise on those sectors which participate in the market and also on all remaining energy sectors. Refined oil products (*REFINED*) and mineral products (*MINERAL*) became net buyers of permits, with drops in emissions equal to -11% and -15% respectively, whereas the metal products sector (*METAL*) became a net seller, with a decrease in emissions equal to 18%. Finally the electricity sector (*ELEC*) neither buys nor sell any of its own permits, with a decrease in emissions equal to 16%. Moreover it is interesting to note that energy sectors like *COAL* and *GAS* experience also an important decrease in their emissions (-17% and -3% respectively). Finally there are also no significative effects on the emissions made by the remaining sectors in the economy which in average reduce their emissions by a -0,3%.

The effects of this environmental policy on the activity levels of sectors are very limited as showed by the small reduction on GDP. The most significative effects are restricted to the energy sectors. The coal sector accounts for biggest contraction on production (-16,9%), followed by natural gas (-3,2%). Electricity and refined oil products sectors, however, experience a slight drop equal to -1.4% and -1.5%. On the one hand, the high indirect taxes on refined oil products at the benchmark reduce the impact of permits price on the costs of production which limits the effects on the level of activity on that sector. On the second hand, thermal power utilities (coal, fuel oil, gas) represent only 40% of the total electricity generation in Spain. In other words, only 40% of production from the electric sector will experience a direct increase in their operating costs. In addition, this causes that electricity is now cheaper in relative terms with respect to fossil fuels and that is encouraging the consumption of electricity through the substitution effects. Besides the technological change on the generation of electricity explains the abrupt drop on the production of coal (a sector excluded from the environmental restrictions).

The remaining non-energy sectors experienced not very significant effects on their activity, ranging from a drop of 0.3% in iron and steel industries (*METAL*) to a null effect on construction (*CONSTRUCT*). The previous results are reasonable if we bear in mind that electricity represents approximately 70% of the final consumption of energy in Spain.

Figure A. Sectorial effects on production and emissions from *real market* scenario.



Source: own calculations.

Wide Market

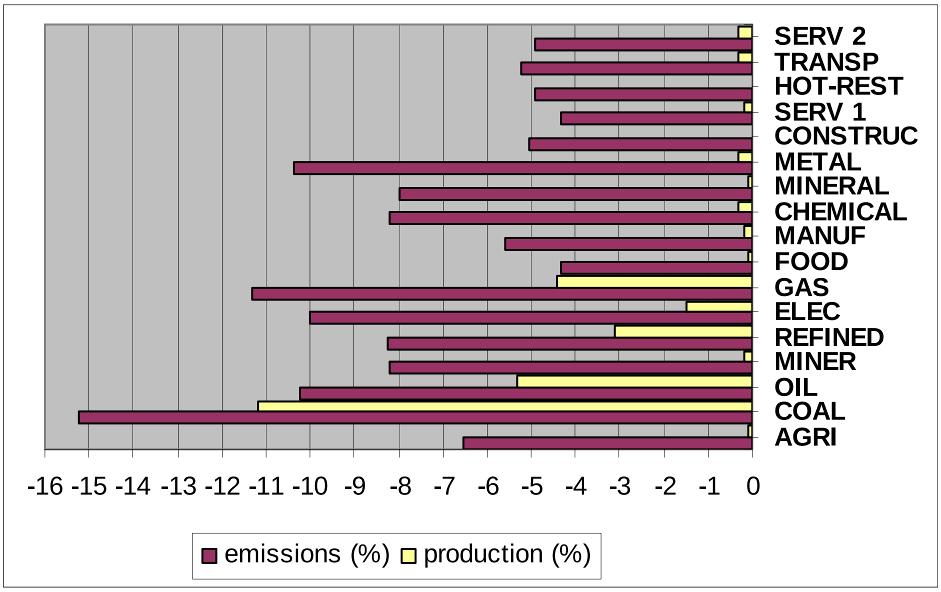
This is a hypothetical scenario simulated to measure the efficiency costs of the restricted nature of the *real market* for permits as it is contained in the Spanish National Plan against greenhouse gases. In order to made a correct interpretation of results the number of permits issued by the government is now an endogenous variable subject to the constraint that both scenarios produce the same reduction on overall CO_2 emissions, that is a -5,63% drop. As a result the government will allocate CO_2 pollution permits between all sectors in the economy free of charge (grandfathering), and will reduce their number by a 7,62% in order to attain the environmental objectives[20].

The costs for the economy of this broader nature of the market for the same environmental objectives are lower than in the previous scenario as expected. GDP decreases now a 0,0235% with respect to the benchmark (at producer prices net of taxes). It represents about one third of the costs from the *real market*. Moreover the

[20] In the *real market* scenario this reduction was equal to 16% between sectors included in the directive.

welfare losses drop by a half and they represent now a 0,027% of benchmark welfare level (measured as equivalent variations).

Figure B. Sectorial effects on production and emissions from *comprehensive market* scenario.



Source: own calculations.

Figure B allow us to understand the effects of this broader pollution market on the level of activity and the emissions in different sectors of our model. Now the reduction on emissions is more evenly distributed following the wide nature of the market. On the one hand the sectors which are not included in the Directive and non energy sectors in general reduce their CO_2 emissions by a -5,5% on average. On the second hand, the remaining sectors (those included in the Directive and energy sectors in general) reduce their emissions in a range between -8% (*MINERAL*) and -15% (*COAL*). The electricity, mineral products and metal sectors are among those which benefit more from the broader nature of the market. The most negatively hitting by the market are natural gas (-11,3%), extraction of metallic and non-metallic nor energetic minerals (-8,2%; *MINER*), and the chemical sector (-8,2%).

It is interesting to note that all sectors included in the Directive and the energy sectors in general became now net sellers of permits. This fact proves that they are the sectors with the lower abatement costs in the economy and justify to some extent their selection to take part in the European carbon market.

If we look to the effects on the production levels we found that they are more negative in general but remain no significative enough for most sectors in the economy. The most significant differences with respect to the effects on production from the *real market* scenario is the change on the activity level of *COAL* (now a 33.7% higher) and on the production for refined oil products (now a 50% lower).

Auctioned Market

Finally we simulate again the wide market but now the permits are auctioned among sectors instead of being allocated free of charge by the government, thus in a way that resembles a carbon tax. As before the number of permits issued by the government is an endogenous variable subject to the constraint that overall CO_2 emissions is reduced by a -5,63%. As a result the government will reduce the number of permits being auctioned by a 7,84% in order to attain the environmental objectives[21].

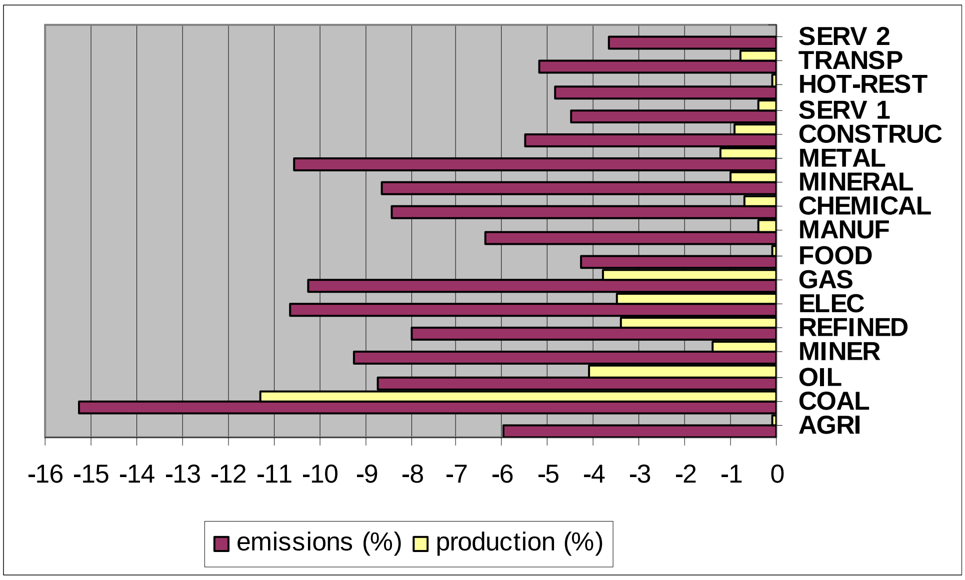
The costs for the economy when pollution permits are auctioned (carbon tax) are greater comparing to any of the previous scenarios as GDP decreases by a 0,0981% with respect to the benchmark (at producer prices net of taxes). It represents a 52% rise of the costs from the *real market*. Consequently the welfare losses increase as well and they represent now a 0,19% of benchmark welfare level (measured as equivalent variations) but it is still not significant. This result corroborates the fears expressed by industrial sectors against carbon taxes as they raise revenues whatever is the level of emissions. Such opposition has stoped plans for a Europen carbon-eenergy tax in the nineties. It validates also the choice made by the European Commission for a limited number of sectors being restricted by the permits market in order to reduce lobbying activities (Boemare and Quirion, 2002).

Figure C allow us to understand the effects of this auctioned market on the level of activity and the emissions in different sectors of our model. The reduction on

[21] In the *real market* scenario this reduction was equal to 16% between sectors included in the directive.

emissions is similar to those found in the *wide market*. If we look to the effects on production we found that a great number of sectors appear to be hitting negatively by the environmental regulation as *MINER*, *ELEC*, *CHEMICAL*, *MINERAL*, *METAL*, *CONSTRUC*, transport services (*TRANSP*), and some services like education, health, veterinary and social services, sanitation, etc. (*SERV2*).

Figure C. Sectorial effects on production and emissions from *auctioned market* scenario.



Source: own calculations.

4. Conclusions

Spanish emissions of greenhouse gases have followed a path of strong growth during recent years. This behavior is incompatible with the objectives of Kyoto for Spain, and in addition, it reflects an inefficient and a very dependent energy system. According to the internal distribution of pollution abatement within the EU in order to fulfill the Kyoto Protocol Spain should reduce it current greenhouse gas emissions by a 16% in the period from 2008 to 2012.

The objective of this work is twofold. On the one hand, to analyse the costs for Spain of fulfilling the European Community objectives of reducing emissions. This is the main contribution of the paper representing the first attempt to our knowledge in the Spanish empirical literature. On the second hand, to show the efficiency and distributional costs from the limited scope for such a market. To this end we simulate different frameworks for a market of CO_2 pollution permits in Spain. The political relevance of this analysis is self evident given that a new European carbon market will be set up in 2005.

The methodology employed is a static applied general equilibrium model for a small open economy. The consumption of energetic assets on the part of industries and institutions has been broken down as much as possible from the national accounting data supplied. This characteristic lends the model sufficient flexibility so that the agents may substitute, in an efficient manner, the consumption of some energy assets for others that are less pollutant. In addition, the model simulates the CO_2 emissions associated with the consumption of fossil fuels. Both characteristics permit the model to minimize the costs of the environmental policy.

We simulate first the market for CO_2 pollution permits as it is contained in the Spanish National Plan against green house gases and it is to be launched in 2005. We call this scenario as the *real market*. Thus we simulate the grandfathering allocation of permits between those sectors included in the European Community Directive. The results obtained show that the costs of reaching the objects set by the EU for Spain are of little significance. The objective of the government to reduce the emissions of greenhouse gases by a 16% (by Directive sectors) would result in an insignificant drop in the GDP, with no costs in terms of employment. The effects on social welfare would be almost null.

The energy sectors are logically the most affected by the environmental regulation, with drops in activity in the range between 18% for coal and 1,5% for electricity and refined oil products. The important consequences on the coal sector despite not being included in the directive (carbon market) are owing to the technological substitution effects within the electricity generation industry (it represents more than 80% of total demand of coal in Spain). The losses in activity in the remaining non-energy sectors are of little significance.

Additionally we simulated the same market but including all producers in the economy. The costs for the economy of this broader nature of the market for the same environmental objectives are lower than in the previous scenario as expected. GDP losses represent about one third of the costs from the market in the Directive and social welfare losses are reduced by a half. Therefore we have proved that there are some efficiency costs from the narrow nature of the market to be launched in 2005. It is interesting to note that all sectors included in the Directive and the energy sectors in general became now net sellers of permits. This fact proves that they are the sectors with the lower abatement costs in the economy and justify to some extent their selection to take part in the European carbon market.

Finally we compare the last scenario, grandfathering allocation of permits between all producers in the economy, with a hypothetical policy where permits are auctioned among sectors in a way that resembles a carbon tax. We concluded that grandfathering allocation of permits ensures a better performance of the Spanish economy as compared to auctioned permits when revenues are given back to the households through lump sum transfers. This result corroborates the fears expressed by industrial sectors against carbon taxes as they raise revenues whatever is the level of emissions. However there is some empirical evidence in the literature concluding that green tax reforms perform better that grandfathering allocation of permits. This issue should be considered for future research in Spain.

Therefore, the conclusions obtained from the available empirical evidence are clear. It is especially advisable to introduce, as soon as possible, public measures for the control of Spanish greenhouse gas emissions. Obviously, these should be introduced through cost-effective instruments of environmental policy like a market of pollution permits that should include all emitters in the economy. Transaction and institutional costs (monitoring and political) advise regulators against a wide market for pollution permits in the economy. Therefore some other policies should be recommended, for example, through a hybrid system of taxes on some sectors and institutions along with an emission commerce system for some specific industrial sectors as the European.

The Spanish National Plan against greenhouse gas emissions already takes into account the possibility of a hybrid regulation of greenhouse gas emissions. The best political option should include the introduction of environmental taxes through a green tax reform. The revenues raised by the carbon tax could finance a reduction on other distorting taxes, like income and labour taxes. The goal of such a measure is to lessen the negative effects of the environmental policy on the economy from a revenue raising instrument (comparing to other recycling options like lump sum transfers) and to provide a positive double dividend. The latter has been proved to be a feasible political option in Labandeira et al (2004).

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Appendix

Production functions in the AGE

$$B_i = \min\left(\frac{KEL_i}{c_{0i}}, \frac{CID_{1i}}{c_{1i}}, \ldots, \frac{CID_{ni}}{c_{ni}}\right) \quad \text{(A1)}$$

$$KEL_i = \alpha_i\left(a_i KL_i^{\frac{\sigma_i^{KEL}-1}{\sigma_i^{KEL}}} + (1-a_i)E_i^{\frac{\sigma_i^{KEL}-1}{\sigma_i^{KEL}}}\right)^{\frac{\sigma_i^{KEL}}{\sigma_i^{KEL}-1}} \quad \text{(A2)}$$

$$KL_i = \alpha_{iKL}\left(a_{iKL} K_i^{\frac{\sigma_i^{KL}-1}{\sigma_i^{KL}}} + (1-a_{iKL})L_i^{\frac{\sigma_i^{KL}-1}{\sigma_i^{KL}}}\right)^{\frac{\sigma_i^{KL}}{\sigma_i^{KL}-1}} \quad \text{(A3)}$$

$$E_i = \alpha_{iE}\left(a_{iE} ELEC_i^{\frac{\sigma_i^{E}-1}{\sigma_i^{E}}} + (1-a_{iE})EP_i^{\frac{\sigma_i^{E}-1}{\sigma_i^{E}}}\right)^{\frac{\sigma_i^{E}}{\sigma_i^{E}-1}} \quad \text{(A4)}$$

$$EP_i = \alpha_{iEP}\left(a_{iEP} COAL_i^{\frac{\sigma_i^{EP}-1}{\sigma_i^{EP}}} + (1-a_{iEP})HIDRO_i^{\frac{\sigma_i^{EP}-1}{\sigma_i^{EP}}}\right)^{\frac{\sigma_i^{EP}}{\sigma_i^{EP}-1}} \quad \text{(A5)}$$

$$HIDRO_i = \alpha_{iPET}\left(a_{iPET} REF_i^{\frac{\sigma_i^{PET}-1}{\sigma_i^{PET}}} + (1-a_{iPET})GAS_i^{\frac{\sigma_i^{PET}-1}{\sigma_i^{PET}}}\right)^{\frac{\sigma_i^{PET}}{\sigma_i^{PET}-1}} \quad \text{(A6)}$$

$$A_i = \lambda_i\left(b_i B_i^{\frac{\sigma_i^{A}-1}{\sigma_i^{A}}} + (1-b_i)IMP_i^{\frac{\sigma_i^{A}-1}{\sigma_i^{A}}}\right)^{\frac{\sigma_i^{A}}{\sigma_i^{A}-1}} \quad \text{(A7)}$$

$$A_i = \gamma_i\left(d_i D_i^{\frac{\sigma_i^{\varepsilon}+1}{\sigma_i^{\varepsilon}}} + (1-d_i)EXP_i^{\frac{\sigma_i^{\varepsilon}+1}{\sigma_i^{\varepsilon}}}\right)^{\frac{\sigma_i^{\varepsilon}}{\sigma_i^{\varepsilon}+1}} \quad \text{(A8)}$$

Consumer functions in the AGE

$$W = \left(s_{UB} LEISURE^{\frac{\sigma^{UB}-1}{\sigma^{UB}}} + (1-s_{UB})UA^{\frac{\sigma^{UB}-1}{\sigma^{UB}}}\right)^{\frac{\sigma^{UB}}{\sigma^{UB}-1}} \quad \text{(A9)}$$

$$UA = \min\left(\frac{SAV_H}{s_{UA}}, \frac{FCHOUSE}{(1-s_{UA})}\right) \quad \text{(A10)}$$

$$FCHOUSE = \varphi_{CFH}\left(s_E EHOUSE^{\frac{\sigma^{CFH}-1}{\sigma^{CFH}}} + s_F FUELOIL^{\frac{\sigma^{CFH}-1}{\sigma^{CFH}}} + (1-s_{EH}-s_{RH})ONE^{\frac{\sigma^{CFH}-1}{\sigma^{CFH}}}\right)^{\frac{\sigma^{CFH}}{\sigma^{CFG}-1}} \quad \text{(A11)}$$

$$EHOUSE_h = \varphi_{EH}\left(s_{EH} ELEC_H^{\frac{\sigma^{EH}-1}{\sigma^{EH}}} + (1-s_{EH})EPHOUSE^{\frac{\sigma^{EH}-1}{\sigma^{EH}}}\right)^{\frac{\sigma^{EH}}{\sigma^{EH}-1}} \quad \text{(A12)}$$

$$ONE = \prod_{i=1}^{17} D_{iH}^{SO_i} \qquad i \neq \{electricity,\ coal,\ natural\ gas,\ refined\ oil\ products\} \quad \text{(A13)}$$

$$EPHOUSE = \varphi_{NEH}\left(s_C COAL_H^{\frac{\sigma^{NEH}-1}{\sigma^{NEH}}} + s_G GAS_H^{\frac{\sigma^{NEH}-1}{\sigma^{NEH}}} + (1-s_C-s_G)REF_H^{\frac{\sigma^{NEH}-1}{\sigma^{NEH}}}\right)^{\frac{\sigma^{NEH}}{\sigma^{NEH}-1}} \quad \text{(A14)}$$

Note for parameters in production and consumption functions. Greek letters stand for scale parameters {α, γ, λ, φ}. Elasticitity of substitution is referenced by σ. Latin letters stand for the share parameters in the producttion and consumption functions {*a, b, c, d, s*}.

Elasticities.

The preferences of the representative household, with relation to the different commodities and services, have been gauged by using the following elasticities of substitution. The elasticity of substitution between fuel for private transport, energy for the home and a commodity aggregated by the remaining commodities is 0.1. The elasticity of substitution between electricity and the remaining energy for the home is 1.5. The elasticity of substitution between coal, natural gas and the remaining refined oil products which provide energy for the household is 1. The previous elasticities are similar to those used in Böhringer and Rutherford (1997), but lower in some cases following the principle of caution. Therefore we could say that the results obtained are somewhat conservative.

Table A1 describes the elesticities of substitution in CES production functions: σ_i^{KEL} is the elsticicity between the composite goods value added (KL) and energy; σ_i^{KL} is the elsticicity between capital and labour; σ_i^{E} is the elasticity between electricity and the composite good primary energies; σ_i^{EP} is the elsticicity between coal and the composite good hydrocarbon fuels; σ_i^{PET} is the elasticity between natural gas and refined oil products; σ_i^{A} is the elasticity between imported goods and domestic production; σ_i^{ε} is the elasticity between exported goods and domestic supply of goods.

Table A.1. Elasticities of substitution in the different activities.

	$\sigma_i^{KEL\ (3)}$	$\sigma_i^{E\ (4)}$	$\sigma_i^{KL\ (1)}$	$\sigma_i^{NE\ (4)}$	$\sigma_i^{PET\ (4)}$	$\sigma_i^{A\ (1)}$	$\sigma_i^{\varepsilon\ (2)}$
AGRIC	0.5	0.3	0.56	0.5	0.5	2.2	3.9
CRUDE	0.5	0.3	1.26	0.5	0.5	2.8	2.9
MIN	0.96	0.3	1.26	0.5	0.5	1.9	2.9
FOOD	0.5	0.3	1.26	0.5	0.5	2.8	2.9
MANUF	0.8	0.3	1.26	0.5	0.5	2.8	2.9
CHEM	0.96	0.3	1.26	0.5	0.5	1.9	2.9
PROMIN	0.96	0.3	1.26	0.5	0.5	1.9	2.9
METAL	0.88	0.3	1.26	0.5	0.5	2.8	2.9
CONSTR	0.5	0.3	1.40	0.5	0.5	1.9	0.7
SERV1	0.5	0.3	1.26	0.5	0.5	1.9	0.7
HOST	0.5	0.3	1.68	0.5	0.5	1.9	0.7
TRANSP	0.5	0.3	1.68	0.5	0.5	1.9	0.7
SERV2	0.5	0.3	1.26	0.5	0.5	1.9	0.7
COAL	0.5	0.3	1.12	0.5	0.5	2.8	2.9
OIL	0.5	0.3	1.12	0.5	0.5	2.8	2.9
ELEC	0.5	0.3	1.26	0.5	0.5	2.8	2.9
GAS	0.5	0.3	1.12	0.5	0.5	2.8	2.9

Source: Drawn up by us for this study.
Notes: (1) GTAP (Hertel, 1997); (2) deMelo and Tarr (1992); (3) Kemfert and Welsch (2000); (4) Böhringer, Ferris and Rutherford (1997).

Table A.2. Sectors in the NAM-1995 and correspondence with the SIOT-1995

Sectors NAM-95	Description	Code SIOT 1995
AGRI	Agriculture, livestock and hunting, silviculture, fishing and aquiculture	SIOT 01, 02, 03
COAL	Extraction and agglomeration of anthracite, coal, lignite and peat	SIOT 04
CRUDE	Extraction of crude oil and natural gas. Extraction of uranium and thorium minerals	SIOT 05
MINER	Extraction of metallic, non-metallic nor energetic minerals	SIOT 06, 07
OIL	Coke, refined oil products and treatment of nuclear fuels	SIOT 08
ELEC	Electricity	SIOT 09
GAS	Natural gas	SIOT 10
FOOD	Food and drink	SIOT 12-15
MANUF	Other manufacturing industries	SIOT 11, 16-20, 31-38
CHEM	Chemical industry	SIOT 21-24
PROMIN	Manufacturing of other non-metallic minerals, recycling	SIOT 25-28, 39
METAL	Metallurgy, metallic products	SIOT 29, 30
CONSTR	Construction	SIOT 40
SERV1	Telecommunications, financial services, real estate, rent, computing, R+D, professional services, business associations.	SIOT 41-43, 50-58, 71
HOTEL-REST	Hotel and restaurant trade	SIOT 44
TRANSP	Transport services	SIOT 45-49
SERV2	Education, health, veterinary and social services, sanitation, leisure, culture, sports, public administrations	SIOT 59-70

Source: Drawn up by us for this study. The Symmetric Input Output Table (SIOT) codes represent the different areas of activity published in INE (2002a).