EFFECTS OF GREEN TAX REFORMS IN SPAIN.
A NEW ANALYTICAL APPROACH INTEGRATING MICRO AND MACRO-ECONOMIC MODELS

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Summary

In recent years, the so-called green tax reforms have become a relevant instrument in the environmental policies of the developed world. These reforms are based on the theory of the double dividend yielded by environmental taxation, which essentially argues in favour of the introduction of such taxation which is revenue-neutral and reduces distortionary taxation. Given the theoretical ambiguity that exists as to the manner and magnitude of the effects of such reforms, this paper proposes a new methodology which enables us to carry out a thorough analysis of the distributive and efficiency consequences. In order to do so, we have integrated a micro-econometric model representing household energy demand and an applied general equilibrium model. The simulation of a hypothetical reform in Spain shows that a tax on CO_2 emissions, with a simultaneous reduction in social contributions, provides a win-win situation (environmental and fiscal). Furthermore, its distributive effects are virtually insignificant and relatively specific.

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1. Introduction

Environmental problems on a global scale, such as climate change, have brought about a renewed and increasing interest in the designing and effects of different government policies. Such policies include the so-called green tax reforms (GTRs), which in the last decade have been put forward and applied[1]. Essentially, a GTR aims to improve environmental and tax efficiency twice over, by introducing an environmental tax and recycling the revenue to reduce distortionary taxation. For example, a tax on fossil fuel consumption contracts demand and therefore the pollution associated with such fuel (the first dividend), and it rises tax revenues which makes it possible to reduce taxation on capital or labour and related distortions (second dividend).

From a theoretical point of view, recycling the revenue obtained by environmental taxation has an efficiency value, as it reduces regulatory costs with respect to a situation with no recycling, known as a *weak double dividend* (Goulder, 1995). This is sufficient to uphold the establishment of GTRs in reality, although the theoretical conditions necessary for a *strong double dividend*, or simultaneously positive first and second dividends, are very restrictive (Bovenberg and Goulder, 2002).

It is necessary, therefore, to resort to economic simulation methods in order to contrast empirically the double dividend hypothesis (the double yielded by environmental taxation). Different papers have analysed the empirical evidence available, concluding that certain GTRs, mainly those that make a reduction in wage contributions possible, can provide a strong double dividend[2]. A large part of literature focuses on questions of efficiency. However in order to assess the changes in wellfare brought about by a GTR it is necessary to be aware of its distributive effects. In particular, distributive consequences are crucial for the eventual practical application of the GTRs.

This paper proposes the use of a new methodology which enables us to carry out a thorough analysis of the efficiency and distributive effects of a GTR. A new analytical approach capable of including the most suitable methods to meet the proposed

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[1] See, for example, Pearce (1991) andy Gago and Labandeira (2000).
[2] See Bosquet (2002) or Gago, Labandeira and Rodríguez (2003).

objectives: a microeconomic household energy demand model and a computable general equilibrium model (CGE). The CGE allows us to know the changes brought about by a GTR in carbon (CO_2) emissions, social welfare, prices and the level of activity of the different sectors and institutions. Subsequently, integrating the results of the CGE in the microeconomic model, it is possible to disaggregate more thoroughly the effects of the GTR on the household and thus analyse the distributive profile of the reform[3].

A fundamental objective of the article is to use this new methodology to understand the economic, distributive and environmental effects of a GTR in Spain. The results of this application show that the introduction of a tax on CO2 emissions involving a reduction in social contributions provides a strong double dividend, its distributive effects being practically insignificant and relatively specific. This new empirical evidence for the Spanish economy is especially useful on account of the lack and incomplete nature of existing literature[4], clearly insufficient in order to be useful when planning essential climate change control policy which our country is faced with in the short term[5].

Furthermore, we believe that in the absence of specific studies such results are useful in order to put forward the effects of a GTR in other developed Mediterranean countries, providing valuable information on the consequences of policies to counter the climate change beyond 2012 in such countries. In this sense, the conclusions of this study are especially interesting as most of the international empirical literature considers that the effects of a GTR are regressive (generally using partial equilibrium methods and applications for northern Europe), which hinders the social and political acceptance of such measures.

The article is made up of three sections, as well as this introduction. In section 2 the methodological approach used, with a description of the theoretical models and their

[3] See Bosquet (2002) or Gago, Labandeira and Rodríguez (2003).

[4] Labandeira and Labeaga (1999) join an input-output model to a microeconomic model in order to analyse the effects of a tax on CO_2 emissions on the distribution of income and the welfare of consumers where tax revenue is recycled using lump-sum transfers. Manresa and Sancho (2001) use a static computable general equilibrium model to simulate a GTR where labour taxation is reduced. This same methodology is used by Gómez, Kverndokk and Faehn (2002), although a market providing CO_2 emission licenses is simulated, where the income they generate serves to finance a reduction in the contributions of non-qualified workers.

empirical implementation, is set out. Section 3 presents the policies considered and the results obtained from simulations with the integrated micro and macroeconomic models. Lastly, section 4 includes the main conclusions of the study and some policy implications.

2. An analytical approach integrating micro and macroeconomic models

In this section the analytical approach used in the study is described. The main methodological contribution consists of discovering the effects of GTRs by means of an empirical exercise that integrates simulations carried out with a general equilibrium model and a microeconomic household energy demand system.

2.1. The general equilibrium model applied.

The model applied is static and has seventeen productive sectors. The production function, especially designed to assess environmental policies[6], is a succession of nested constant elasticity of substitution (CES) functions in which different productive factors and energies (capital, *K,* and work, *L*) are combined, as illustrated in Figure 1. As a result, the production in sector *i*, measured in units and indicated by B_i, is a combination of semi-manufactured commodities and the remaining productive factors (*K*, *L*, energy), through a Leontief function.

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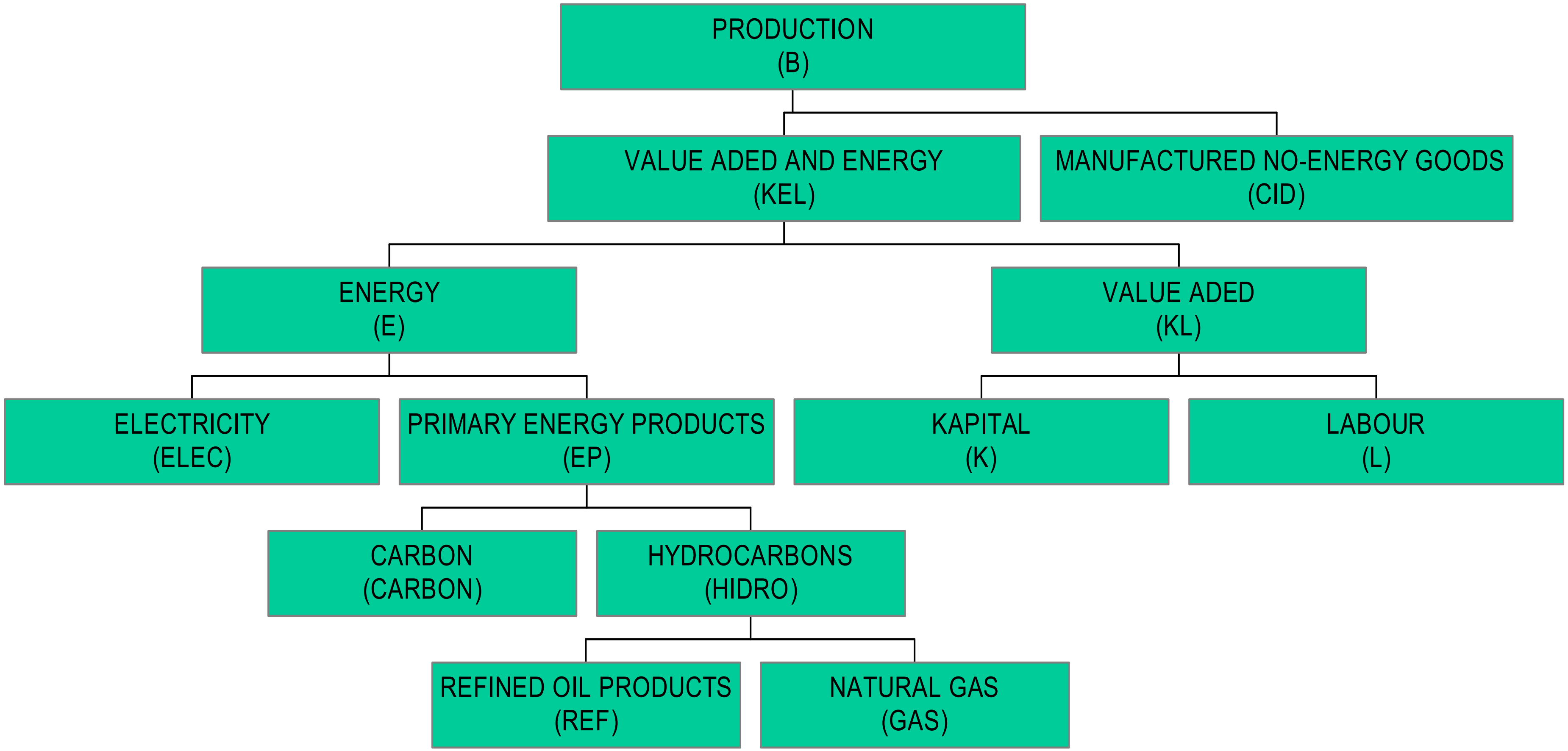
[5] By the beginning of 2002 Spain had increased its CO_2 emissions by more than 30% with respect to 1990, doubling the limit permitted by the EU's internal agreement and in order to comply with the Kioto Protocol in 2010.

[6] The AGEM structure used in our empirical analysis is similar, although with some changes, to that used by Böhringer, Ferris and Rutherford (1997). The model is detailed in the Appendix.

Figure 1. Chained production technology structure



Source: Drawn up by us for this study

The total supply of the commodity *i* in the economy, A_i, is a good made up via a CES function by national production and imports, IMP_i, assuming, as is usual, that commodities of different origins are imperfectly substitutable products. The end destination of the supply is the export market, EXP_i, or domestic consumption, D_i, determined via a constant elasticity of transformation (CET) function[7].

Following the breakdown of Spanish national accounts, there are five institutions in the economy[8]: a representative household, a public sector, a foreign sector, non-profit household-serving institutions (NPHSIs)[9] and corporations. In general, they receive capital income, carry out net transfers with other institutions and make savings in order to balance their budget[10]. 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 corporate income tax, R_{SOC}, household income tax, R_{CONS}, consumption tax, *RD*, production tax, *RB*, tax on wages, *RL*, and an environmental tax on CO_2 emissions, *RE*, which initially is nil. It also obtains capital income, K_{GOB}, and carries out net transfers with other institutions, TR_{GOB}. Public revenue is used for consumption, CF_{GOB}, a commodity made up of different commodities and services via a Cobb-Douglas function. *DP* measures the end balance (deficit) of the public budget. Thus,

$$\overline{DP} = r \cdot \overline{K}_{GOB} + \overline{R}_{SOC} + R_{CONS} + RB + RD + RL + RE + \overline{TR}_{GOB} - CF_{GOB} \tag{3}$$

The representative household has a fixed endowment of time, *TIME*, which it can use for leisure consumption or to offer work, *L*, at a marginal *w* price. The household obtains labour and capital income, K_{CONS}, and carries out transfers with other institutions, TR_{CONS}. The net income available, Y_{CONS}, is obtained by taking payment of an income tax and employee wage contributions away from previous gross income, R_{CONS} and SS_{CONS}, respectively. Thus,

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7 See Shoven and Whalley (1992) for a description on how international commerce is treated in CGE models.
8 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).
9 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.

$$Y_{CONS} = r \cdot \overline{K}_{CONS} + w \cdot (1 - SS_{CONS}) \cdot L + \overline{TR}_{CONS} - R_{CONS} \tag{4}$$

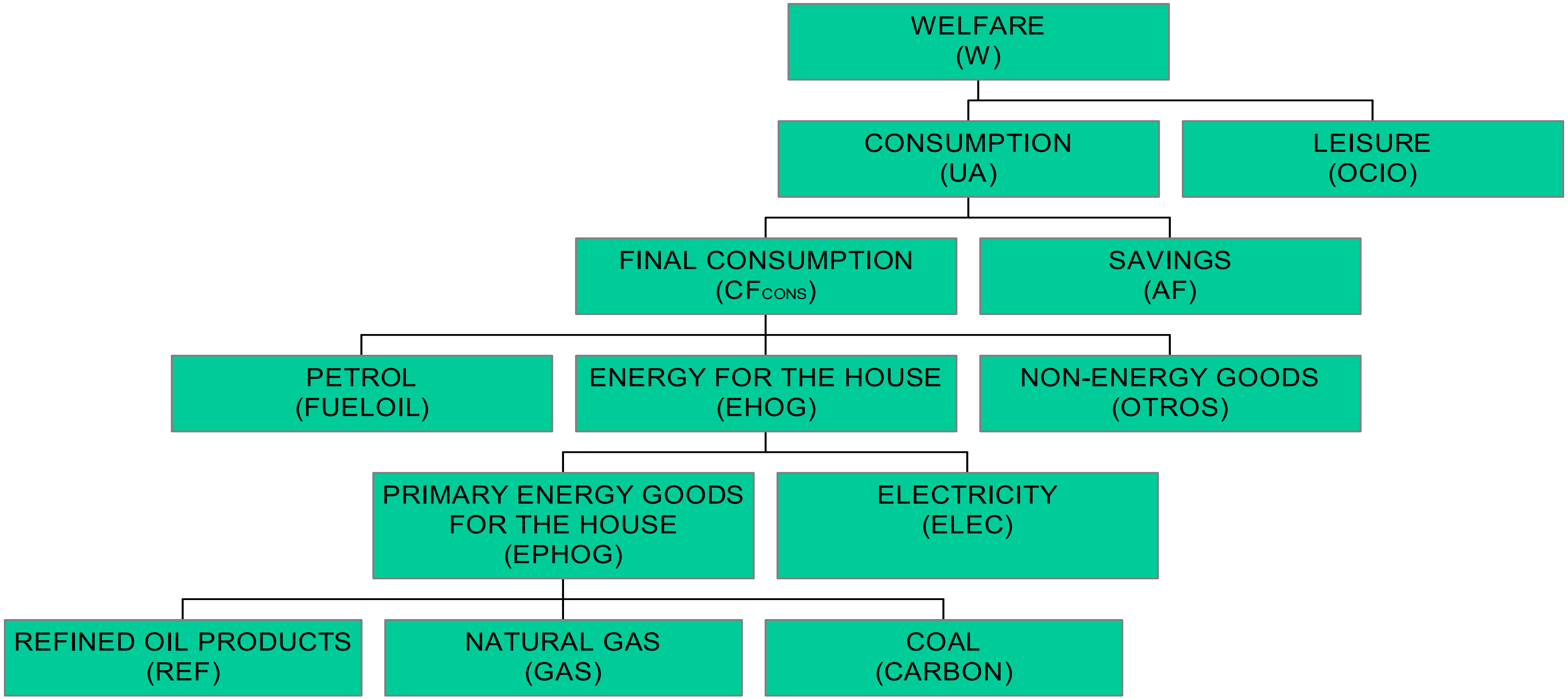
The consumer maximises welfare, *W*, in accordance with the budget restraint. The level of utility depends positively on leisure consumption, *OCIO*, and on the consumption of other commodities, *UA*, and negatively on the volume of CO_2 emissions, *CO2*. As can be seen in Figure 2, nested CES functions are used, with special attention being paid to the consumption of energy. Thus, an important contribution of the CGE is the distinction between household energy products (electricity, coal, natural gas, refined oil products), energy for private transport and other energy products[11]. It is assumed, as in Böhringer and Rutherford (1997), that consumers have a marginal propensity to save from the income available to them, Y_{CONS}. In order to simplify the model further, we assume that the consumption of commodities and services carried out by the representative household abroad, *CR*, is an exogenous variable (mainly tourism).

$$\max \qquad W = \varphi_{UB}\left(s_{UB}OCIO^{\frac{\sigma^{UB}-1}{\sigma^{UB}}} + (1 - s_{UB})UA^{\frac{\sigma^{UB}-1}{\sigma^{UB}}}\right)^{\frac{\sigma^{UB}}{\sigma^{UB}-1}} - \phi \cdot CO2 \tag{5}$$

[10] Capital endowments and transfers are exogenously determined. Because of this reson savings made by corporations is a residual in their budget restriction (made up by savings, capital rents and transfers) in order to counterbalance the change in capital remuneration.

[11] The distinction between energy for the household and other types of energy is common in microeconomic models which analyse household energy consumption (Baker, Blundell and Micklewright, 1989). Other energy commodities is a commodity formulated via a Cobb-Douglas function.

Figure 2. Chained household consumption function structure



Source: Drawn up by us for this study

Domestic consumption, D_i, is the sum of comsumption by the government consumption, D_{iG}, the NPHSIs, D_{iISFL}, the representative household, D_{iH}, the gross formation of capital, D_{iINV}, or consumption as intermediate goods, CID_{ij}, and energy sources, E_i, by sectors.

The saving in the economy is defined endogenously by each one of the institutions. The macroeconomic equilibrium of the model is determined by the financing capacity or need of the economy faced with foreign markets, *CAPNEC*, equal to the difference between national saving and investments, *INV* (aggregated by means of a Leontief function regarding the different commodities used for the gross formation of capital),

$$PINV \cdot INV = PINV \cdot \left(AF_{CONS} + AF_{SOC} + AF_{ISFL} \right) + \overline{DP} - \overline{CAPNEC} \quad (6)$$

A small, open economy which exchanges commodities and services with other countries and which carries out net transfers, TR_{RM}, is assumed. The amount of commodities and services consumed by non-residential households in Spain (mainly tourism) is considered an endogenous variable, given that it is impossible to represent the budget constraint. However, the spending that takes place is an endogenous variable of the model, *CNR*, and depends on the relative prices in the economy. Exchange rates do not exist, PXM_i being the international prices[12]. Therefore,

$$\overline{CAPNEC} = \sum_{i=1}^{n} \overline{PXM}_i \cdot EXP_i + \overline{TR}_{RM} + CNR - \sum_{i=1}^{n} \overline{PXM}_i \cdot IMP_i - \overline{CR} \quad (7)$$

Capital and labour demand minimises the cost of the firm value added. Capital supply is inelastic, perfectly mobile between sectors, but immobile internationally. As in Böhringer and Rutherford (1997), a competitive labour market, and, therefore, an economy without involuntary unemployment, is assumed[13]. Labour supply is also perfectly mobile between sectors, but immobile internationally.

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[12] We assume that the policy simulated has little significant impact on the exchange rate of the euro, as Spain's major business partners are countries which belong to the European monetary union.

[13] In our model, which depicts a representative household or consumer, the amount of employment in equilibrium represents the work carried out by the working population and leisure consumption in reality reflects the leisure consumed by this working population. Therefore, the possible changes in the labour supply estimated by the model refer to changes in the labour supply of the working population (Goulder, Parry and Burtaw, 1997).

The model simulates household CO_2 emissions, *CO2*, generated during the combustion processes of the different primary energy sources (coal, refined oil products, natural gas). In particular, the CO_2 emissions produced by the different sectors, $CO2_i$, and by households, $CO2_H$, as they are the only institutions that consume energy in Spain's national accounts for 1995,

$$CO2 = CO2_H + \sum_i^n CO2_i \tag{8}$$

The information used for implementing the model comes from a national accounting matrix for the Spanish economy (NAM-95) erected on the basis of the national accounts for 1995[14] following the ESA-95. The SAM-95 at basic prices is used in order to elaborate the NAM-95[15], as well as the destination tables (DT) at market prices[16] and at basic prices, as well as the symmetric input-output table (SIOT) at basic prices, published in INE (2002a).

Moreover, the NAM-95 contains the CO_2 emissions for each sector and institution when they consume the different energy products. In order to elaborate the environmental information a procedure similar to that used in the environmental accounts published in INE (2002b) has been followed. Given that in said publication only the total CO_2 emissions of each economic sector are reflected, we have disaggregated them, in terms of whether they derived from coal combustion, refined oil products or natural gas (see Table 1). The environmental information referring to Spain for 1995 can be found in IEA (1998), and in Ministry for the Environment (2000).

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[14] For a detailed description of the NAM-95 and the procedure used, see Rodríguez (2003).

[15] The SAM-95 is an unpublished NAM for 1995, drawn up by Melchor Fernández (Department of Economic Analysis, Santiago de Compostela University) in which sectors have not been disaggregated.

[16] The destination table (DT) at mmarket prices has not yet been published. This information has been obtained directly from the INE (Spanish Statistics Office).

Table 1. CO_2 in Spain, 1995 (metric tonnes and relative weights, %)

· *Products* *Sectors*	COAL	REFINED OIL PRODUCTS	NATURAL GAS	TOTAL (tm)	TOTAL (%)
AGRIC	17.102	5.440.224	141.844	5.599.170	2.39
COAL	2189	371.528	0	373.717	0.16
CRUDE	0	64.743	26.335	91.078	0.04
MINING	339.442	995.832	52.038	1.387.312	0.59
OIL	340.399	4.996.648	65.284	5.402.331	2.31
ELEC	41,564,824	15,604,953	1,496,967	58,666,744	25.05
GAS	0	206,183	4179	210,362	0.09
FOOD	31,741	2,894,311	878,816	3,804,868	1.62
MANUF	305,374	3,510,204	1,482,696	5,298,274	2.26
CHEM	642,490	14,469,673	2,514,710	17,626,873	7.53
PROMIN	388,285	4,184,422	2,381,854	6,954,561	2.97
METAL	4,898,848	2,380,126	2,105,815	9,384,789	4.01
CONSTRUC	360,101	4,153,323	31,381	4,544,805	1.94
SERV1	319,877	8,942,128	2,437,283	11,699,288	5.00
HOT-REST	109,043	2,587,858	1,287,789	3,984,690	1.70
TRANSP	45,286	26,208,830	62,919	26,317,035	11.24
SERV2	966,882	8,425,951	2,239,853	11,632,686	4.97
HOUSEHOLDS	1,145,974	55,090,405	4,959,956	61,196,335	26.13
TOTAL ECONOMY	*51,477,857*	*160,527,342*	*22,169,719*	*234,174,918*	*100.00*

Source: Drawn up by us for this study.
Notes: 1) CO_2 emissions produced in combustion processes. 2) Refined oil products: fuel for transport, butane and propane gas, fuel oil, etc. 3) For a definition of the productive sectors, see the Appendix.

Based on the information obtained from the NAM-95 the model's parameters can be gauged: tax rates, and technical coefficients for the production, consumption and utility functions. The criterion used is that the CGE is capable of reproducing the information contained in the NAM-95 as a solution or optimum equilibrium, which will be used as a benchmark[17]. In the initial equilibrium, the prices are equal to the unit, the effects brought about by the reforms being estimated as relative changes in production and relative prices. Certain parameters, such as elasticities of substitution,

[17] For a brief introduction to this methodology, see Shoven and Whalley (1992). The general equilibrium model has been programmed using GAMS/MPSGE, and the gauging has been implemented following the method proposed in Rutherford (1999), using the solver-algorithm PATH.

have not been gauged but taken from literature, described in greater detail in the Appendix.

It has been our desire to gauge an elasticity of the labour supply in the face of changes in wages equal to -0.4, similar to that estimated for Spain in Labeaga and Sanz (2001)[18]. 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 of the results obtained using this model, increasing and reducing the labour elasticity value by 50%. From this analysis we can conclude that the results obtained from the CGE are robust compared to significant changes in the elasticity of the labour supply.

2.2. Household energy demand microeconomic model

The theoretical model on the basis of which we have estimated the empirical model is the quadratic extension proposed by Banks, Blundell and Lewbel (1997) from Deaton and Muellbauer's almost ideal demand model (1980). Therefore, the model can capture the existence of different elasticities of substitution throughout the household income distribution function, showing if certain commodities are basic necessities or luxury goods at different points along said distribution,

$$w_{iht} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \log p_{jht} + \beta_i \log \frac{x_{ht}}{a(p_{ht})} + \frac{\lambda_i}{b(p_{ht})} \left(\log \frac{x_{ht}}{a(p_{ht})} \right)^2 \qquad (9)$$

$$\log a(p_{ht}) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \log p_{iht} + \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \log p_{iht} \log p_{jht} \qquad (10)$$

$$b(p_{ht}) = \prod_{i=1}^{n} p_{iht}^{\beta_i} \qquad (11)$$

where *i, j =1, 2, ...n* represents the consumer goods considered in the model {electricity, natural gas, Liquid Petroleum Gases (butane, mainly, and propane, LPG), fuel for private transport (motor fuel), public transport and other non-durable goods}, w_{iht} is

[18] For a brief description of the empirical work applied to Spain in which the elasticity of the labour supply as opposed to changes in salaries are estimated, see Rodríguez (2003).

the participation of the commodity *i* in the total household spending *h* at the time *t*. The price vector faced with by each household at any given moment is p_{iht}, and x_{ht} is the real total income of each household, deflated by a Stone price index. To make the demand system coherent with the consumer theory, we impose symmetry and zero degree homogeneity conditions in prices and income.

In order to estimate the model we use the Family Expenditure Survey (ECPF) for the period 1985-1995. We estimate the model in third-order moving averages instead of using the original information as is usual in literature, on account of important problems of infrequency in the purchase of energy products[19].

In order to simulate the GTR we will take the changes in the prices estimated by CGE as exogenous information. The main difficulty involved is how to make the relative prices estimated by the CGE compatible with the absolute prices used by the micro model. With this aim in mind, the changes in the relative prices estimated by the CGE in relation with the consumer price index (CPI) are calculated first. Then the new relative (post-reform) prices with respect to the CPI are calculated for the micro model, by multiplying the initial (pre-reform) relative prices by the exchange rate on relative prices obtained from the CGE[20].

3. Results of the integrated micro-macro analysis of a GTR in Spain

3.1. The reforms simulated

In the study we analyse the economic and environmental effects of two tax policies aimed at controlling climate change on which certain international environmental evidence exists. Firstly, we study the effects of a GTR in which a tax on CO_2 emissions is introduced and the entire revenue of which is used to finance a reduction in the social contributions supported by employers. Secondly, we analyse the effects of such a tax

[19] See Labandeira, Labeaga and Rodríguez (2003) for a more detailed analysis of the model and its estimation.

[20] In order to gauge the CGE, we assume that the prices on the benchmark are equal to the unit and the quantities equal to the monetary values in the NAM-95. Therefore, the changes in each of the prices with respect to the CPI in fact represent an index of how the relationship between the two ought to change.

when the revenue it generates is returned entirety to the households via lump sum transfers.

In any case, the environmental tax used in each of the reforms is equivalent to a tax rate of 12.28€ per tonne of CO_2 emitted into the atmosphere, according to scientific literature's most plausible results[21]. The environmental tax does not levy a tax directly on the emissions of each sector or institution but on the consumption of the fossil fuels responsible for pollution (coal, refined oil products and natural gas).

The taxes are programmed *ad valorem* in the general equilibrium model. However, the environmental tax simulated in the GTR is *ad quantum*, $ACCISA_i$. In order to make both objectives compatible, the tax rate of the *ad valorem* environmental tax, TE_i, is an endogenous variable of the model. In equilibrium, the revenue obtained by both taxes must be identical. With this objective we use the restriction,

$$TE_i \cdot PD_i \cdot (1 - TD_i + SD_i - TE_i) \cdot D_i = D_i \cdot ACCISA_i \quad (12)$$

3.2. Results of the applied general equilibrium model

3.2.1. Effects of a GTR which foresees a reduction in social security contributions

The most immediate effect of this GTR is an 11.7% reduction in the marginal rate paid by employers in social security contributions, a reduction financed by the new environmental tax on fossil fuels. The reduction in labour costs stimulates labour demand, which grows by 0.1%. In turn, a greater working rate creates the tension necessary to produce a 0.2% increase in real labour income. However, real capital income falls by 0.7%. The GTR reduces economic wealth by 0.72% in terms of GNP at basic prices (GNPbp), although the GNP at market prices (GNPpm) experiences a 0.16% growth.

Table 2 shows the sectorial effects of the GTR on production, consumption prices and pollutant emissions. The GTR affects the production of primary energies and, to a lesser

[21] This figure comes from the estimation of the real marginal costs of emitting a tonne of CO_2 between 1991-2000, a methodology which is in keeping with the policy simulated (unilateral action of a country of relatively little importance in terms of emission). For more on this subject, see Labandeira and Labeaga (2002).

extent, the electricity sector, negatively. The remaining sectors experience more or less significant increases in their activity. Insofar as real prices are concerned, they all drop, except for the energy, mining and transport service sectors.

The results also show that the GTR is an efficient control instrument, reducing CO_2 emissions by 17,980,351 tm of CO_2, or by 7.68% in relative terms. The sectors which experience the greatest reductions are, in this order, the electricity sector (*ELEC*), households, transport services (*TRANSP*), and the chemical sector (CHEM), although they are not the ones which make a greater effort in relative terms.

Table 2. Changes in sectorial production, emissions and real prices (in percentage)

	GTR			Lump sum		
	Production	**CO_2**	$p_i/_{CPI}$ **(1)**	**Production**	**CO_2**	$p_i/_{CPI}$ **(1)**
AGRIC	+ 0.9	-6.80	- 0.5	- 0.3	-8.08	- 0.99
COAL	- 9.2	-15.74	+ 26.65	- 11.7	-17.38	+ 26.63
CRUDE OIL	- 6.7	-13.37	+ 0.2	- 9.5	-15.93	- 0.99
MINING	+ 0.7	-10.37	+ 0.3	- 2.8	-13.09	+ 0.1
OIL	- 6.7	-12.84	+ 19.64	- 7.8	-13.83	+ 18.71
ELEC	- 0.9	-8.44	+ 3.31	- 2.0	-9.57	+ 2.87
GAS	- 8.3	-14.89	+ 16.13	- 9.2	-15.73	+ 15.25
FOOD	+ 0.6	-6.52	- 0.7	- 0.3	-6.99	- 0.79
MANUF	+ 2.2	-7.51	- 0.9	- 1.3	-9.84	- 0.69
CHEM	+ 1.0	-11.19	- 0.2	- 1.9	-12.98	- 0.2
PROMIN	+ 0.4	-10.81	- 0.1	- 1.8	-12.16	+ 0.1
METAL	+ 1.8	-8.81	- 0.3	- 2.3	-12.01	- 0.3
CONSTR	+ 0.2	-8.25	- 0.8	- 1.3	-9.20	- 0.59
SERV1	+ 0.8	-6.59	- 1.0	- 0.9	-7.83	- 0.99
HOT-REST	+ 0.1	-6.80	- 0.7	- 0.1	-6.87	- 1.09
TRANSP	+ 0.3	-7.68	+ 0.4	- 1.8	-9.28	+ 0.5
SERV2	+ 0.3	-7.55	- 1.3	+ 0.2	-7.04	- 0.79
HOUSEHOLD		-5.22			-5.39	
TOTAL CO_2		*-7.68*			*-8.68*	
CPI (2)			*- 0.2*			*+ 1.0*

Source: Drawn up by us for this study.
Notes: (1) The price changes in percentage terms are calculated as changes in the market prices in respect of the CPI. (2) The changes in the CPI in percentage terms are calculated as changes in the CPI in respect to the price of the numeraire in the model (labour price).

Social welfare, measured as equivalent variation in real terms, experiences a 251.3 million euro increase. The environmental profits of the GTR are calculated on the assumption that the environmental tax expresses the monetary damages brought about by pollutant emissions. That is to say, each tonne of CO_2 emitted into the atmosphere causes damage estimated at 12,28€, that is, ϕ=12.28. In this way, the environmental changes brought about by the GTR provide a first (environmental) dividend of 221.2 million euros, and a second (fiscal) dividend of only 35 million euros.

3.2.2. Effects of an environmental tax involving lump sum transfers

Below we will analyse the results of a reform in which the only aim is to control CO_2 emissions. The introduction of the environmental tax reduces economic wealth in terms of the GNP at basic prices (GNPpb) by 0.82%, while the GNP at market prices (GNPpm) hardly changes, experiences a 0.05% growth. A lower level of economic activity causes a lower labour demand (-0.2%), and a significant drop in real labour and capital income (-1.78% and -0.99%, respectively).

With respect to the reform above mentioned, the different energy sectors have to bear an even more negative impact (see Table 2). Furthermore, some of the sectors which would profit most from the GTR now form a part of the group of non-energy sectors most negatively affected, such as, for example, the metallurgic and metal products sector (*METAL*), other manufacturing sectors (*MANUF*), or the chemical products sector (CHEM). In keeping with the poor economic results, the environmental tax along with lump sum transfers reduces CO_2 emissions 1% more than the GTR.

The effects of the environmental tax in combination with lump sum transfers on social well-being are clearly even worse. Non-environmental wellfare is reduced by 0.13%, understanding that it is not directly associated with changes in CO_2 emissions, valued at a loss of 501.5 million euros. The environmental profits increase social wellfare by 247 million euros. As a consequence of these partial effects, social wellfare experiences a loss of 254.3 million euros under this second reform.

3.3. Results of the household energy demand model

The aim of this section is to disaggregate the effects estimated by the CGE of previous environmental policies on household consumption. Table 3 reflects the changes in percentage terms of the market prices (sales price) after each reform, which would be supplied to the energy demand model. It also shows the change in (average) household spending for each of the commodities. The main spending increases occur in primary energies (gases and motor fuels). Expenditure on food, non-alcoholic drinks and other non-durable commodities is reduced, although insignificantly in relative terms. However, it is precisely these groups which represent a higher proportion in the household shopping basket, therefore total spending is slightly reduced.

In general, a situation arises whereby energy products are replaced by other non-energetic products, now cheaper in relative terms, and also by motor fuels for private transfer in favour of public transport. However, replacing LPGs with natural gas is surprising, when natural gas is the most expensive in either of the two reforms. This is probably due to the high level of heterogeneity of households (natural gas consumption occurs in households living in large cities).

Table 3. Changes in market prices and average spending in percentage terms

	GTR		**Lump sum**	
	prices	**Av. spending**	**prices**	**Av. spending**
Electricity	+ 3.31	+ 1.09	+ 2.87	+ 0.92
Natural gas	+ 16.13	+ 19.07	+ 15.25	+ 18.06
LPG	+ 16.13	+ 12.11	+ 15.25	+ 11.56
Motor fuels	+ 19.64	+ 10.82	+ 18.71	+ 10.28
Public transport	+ 0.40	+ 1.21	+ 0.50	+ 1.25
Food and drink	- 0.65	- 0.61	-0.84	- 0.77
Others, non-durable	- 0.89	- 0.77	-0.82	- 0.72

Source: Drawn up by us for this study.
Note: The spending changes in the table correspond to the average of households in the sample. The estimation was made for the third quarter of 1995.

Table 4 reflects the changes in total spending per income groups, dividing the population into deciles. The modifications in the total spending of the different households are of little significance, in such a way that neither are significant distributive effects. The households which belong to the last two deciles profit the most from either of the reforms, the least fortunate being those which belong to the fourth and fifth deciles. It should be borne in mind that the micro model only analyses the effects of the reforms on spending and not on income. Thus, the introduction of the environmental tax involving the return of its income in the form of lump sum transfers probably generates a significant improvement in the distribution of income.

Table 4. Distributive effects of the tax reforms.
Difference in average spending per decile (euros) and percentage increases

Decile	GTR		Lump sum	
	€	%	€	%
1º	- 1.46	- 0.13%	- 2.08	- 0.19%
2º	- 1.82	- 0.10%	- 2.68	- 0.15%
3º	- 3.06	- 0.14%	- 4.02	- 0.18%
4º	- 1.58	- 0.06%	- 2.75	- 0.10%
5º	- 1.91	- 0.06%	- 3.23	- 0.10%
6º	- 4.24	- 0.12%	- 5.51	- 0.15%
7º	- 5.43	- 0.13%	- 6.85	- 0.16%
8º	- 4.87	- 0.10%	- 6.28	- 0.13%
9º	- 10.32	- 0.17%	- 11.74	- 0.19%
10º	- 19.88	- 0.21%	- 20.48	- 0.22%

Source: Drawn up by us for this study.
Note: Estimation for the third quarter of 1995

Table 5 shows the effects of both reforms on certain groups of households. The distributive effects of the reforms are also of little significance. Those who benefit the most are households in which the head of the family is retired, households in which there are no children under sixteen and households whose habitual residence is in the large cities. The households favoured the least under the reforms are those found in municipalities with less than 10,000 inhabitants (rural). In spite of all this, not all the households have gained from the reforms. The last two lines in Table 5 refer to the number of households that gain (those which obtain positive net saving in their spending) and that lose out (negative net saving in their spending) under the reforms. 71.29% of the households have enjoyed net saving under the GTR, whereas this figure rises to 74.82% under an environmental reform involving lump sum transfers.

Table 5. Distributive effects of environmental reforms on certain household groups. Average spending (euros) and increases

Family group	GTR		Lup sum	
	€	%	€	%
Retired	-5.34	- 0.16%	-6.56	- 0.20%
No children	-6.38	- 0.18%	-7.32	- 0.20%
2 children	-4.51	- 0.10%	-5.85	- 0.13%
4 children	-4.63	- 0.13%	-6.51	- 0.18%
Rural	-2.43	- 0.07%	-3.79	- 0.11%
Urban	-7.12	- 0.17%	-8.08	- 0.20%
No. those who gain	2225	71.29%	2335	74.82%
No. those who lose	896	28.71%	786	25.18%

Source: Drawn up by us for this study.
Note: Estimation made for the third quarter of 1995.

Table 6 indicates that the environmental effects estimated for households by the microeconomic model are similar to those obtained by the CGE, which reinforces the results. However, the microeconomic model offers some additional information. The GTR reduces sulphur dioxide (SO_2) emissions, the gas which causes the acid rain phenomenon, by approximately 10%, whereas it only reduces nitrogen oxide (NO_x) emissions, which cause health problems as well as acid rain, by 3.63%. The results obtained when the income from the environmental tax is returned to the public through lump sum transfers are similar, although somewhat more limited.

Table 6. Environmental effects of the reforms. Modification in household emissions in percentage terms

	CO_2		SO_2		NOx	
	GTR	**Fixed sum**	**GTR**	**Fixed sum**	**GTR**	**Fixed sum**
Electricity	-10.63%	-9.61%				
Natural gas	+13.15%	+12.90%				
LPG	-14.10%	-13.30%				
Motor oils	-1.96%	-1.94%				
Total	*-5.44%*	*-5.03%*	*-9.88%*	*-8.95%*	*-3.63%*	*-3.42%*

Source: Drawn up by us for this study.
Note: Estimation made for the third quarter of 1995.

4. Conclusions.

This article provides information on the effects of different tax policies on climate change control in Spain. A hypothetical GTR is simulated based on a tax on CO_2 emissions and simultaneous reduction in social security contributions, as well as a tax package in which the revenue obtained by the previous environmental tax is recycled by means of lump sum transfers.

In order to do so, we have used a new methodological approach, integrating different methods of analysis to study such policies and improving the calculation of the effects and the reliability of the results considerably. We combine the use of a static general equilibrium model, in order to understand the effects of the reform on different economic sectors, with a microeconomic household energy demand model which allows us to disaggregate the global results.

Our results indicate that a GTR with a 12.28€ tax per tonne of CO_2 emitted reduces emissions of this pollutant in Spain significantly. It also provides important non-environmental benefits as it reduces the distortions created by the tax system in force, slightly increasing employment and improving social wellfare. That is, it provides a positive strong double dividend (environmental and fiscal).

As was to be expected, the effects of the GTR on production are very uneven, activity in energy-intensive sectors being reduced while increasing in other sectors. The effects on market prices are also variable, as prices in energy-intensive sectors increase, whereas they are slightly reduced in the most important goods in the household shopping basket.

With respect to the distributive effects of the GTR, the disaggregated effects on the different households are of little significance, which does not mean that that there are no agents negatively affected by the GTR. This result is interesting as most international empirical literature considers that the effects of a GTR are regressive, although generally through partial equilibrium methods. In any case, this coincides with other empirical evaluations which indicate the low level of regression of energy taxation in Spain.

A tax reform with the same environmental tax but without a reduction in distortionary taxation is only more effective in controlling CO_2 emissions and has a different impact on sectorial activity. In any case, this policy is inferior to a GTR insofar as its effects on social welfare and distribution in Spain is concerned.

Consequently, and in the face of the need to act in order to control CO_2 emissions in Spain on account of existing international commitments, the policy implications which can be extracted from this study seem clear. It is possible to significantly reduce carbon dioxide emissions in Spain by means of a GTR and simultaneously achieve an improvement in non-environmental social welfare at no distributive cost.

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APPENDIX. The computable general equilibrium model (CGE)

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 and a line on top. The parameters of the model are written in Greek and Latin type. There are n productive sectors (*i,j=1, ..., n*) and, consequently, n consumer commodities.

Production

$$\min_{KEL,CID} \quad PB_i \cdot (1-TB_i+SB_i)\cdot B_i = PKEL_i \cdot KEL_i + \sum_{j=1}^{n} PD_j \cdot CID_{ji} \qquad s.t. \quad B_i = \min\left(\frac{KEL_i}{c_{0i}}, \frac{CID_{1i}}{c_{1i}}, ..., \frac{CID_{ni}}{c_{ni}}\right) \quad (A1)$$

$$\min_{KL,E} \quad PKEL_i \cdot KEL_i = PKL_i \cdot KL_i + PE_i \cdot E_i \qquad s.t. \quad KEL_i = \alpha_i \left(a_i KL_i^{\frac{\sigma_i^{KEL}-1}{\sigma_i^{KEL}}} + (1-a_i) E_i^{\frac{\sigma_i^{KEL}-1}{\sigma_i^{KEL}}} \right)^{\frac{\sigma_i^{KEL}}{\sigma_i^{KEL}-1}} \quad (A2)$$

$$\min_{K,L} \quad PKL_i \cdot KL_i = r \cdot K_i + w \cdot (1+SS_i)\cdot L_i \qquad s.t. \quad KL_i = \alpha_{iKL} \left(a_{iKL} K_i^{\frac{\sigma_i^{KL}-1}{\sigma_i^{KL}}} + (1-a_{iKL}) L_i^{\frac{\sigma_i^{KL}-1}{\sigma_i^{KL}}} \right)^{\frac{\sigma_i^{KL}}{\sigma_i^{KL}-1}} \quad (A3)$$

$$\min_{ELEC,EP} \quad PE_i \cdot E_i = PELEC \cdot ELEC_i + PEP_i \cdot EP_i \qquad s.t. \quad E_i = \alpha_{iE} \left(a_{iE} ELEC_i^{\frac{\sigma_i^{E}-1}{\sigma_i^{E}}} + (1-a_{iE}) EP_i^{\frac{\sigma_i^{E}-1}{\sigma_i^{E}}} \right)^{\frac{\sigma_i^{E}}{\sigma_i^{E}-1}} \quad (A4)$$

$$\min_{CARBON,HIDRO} \quad PEP_i \cdot EP_i = PCAR \cdot CARBON_i + PHIDRO_i \cdot HIDRO_i$$

$$s.t. \quad EP_i = \alpha_{iEP} \left(a_{iEP} CARBON_i^{\frac{\sigma_i^{EP}-1}{\sigma_i^{EP}}} + (1-a_{iEP}) HIDRO_i^{\frac{\sigma_i^{EP}-1}{\sigma_i^{EP}}} \right)^{\frac{\sigma_i^{EP}}{\sigma_i^{EP}-1}} \quad (A5)$$

$$\min_{REF,GAS} \quad PHIDRO_i \cdot HIDRO_i = PREF \cdot REF_i + PGAS \cdot GAS_i$$

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

$$\min_{B,IMP} \quad PA_i \cdot A_i = PB_i \cdot B_i + \overline{PXM}_i \cdot IMP_i \qquad s.t. \quad A_i = \lambda_i \left(b_i B_i^{\frac{\sigma_i^{A}-1}{\sigma_i^{A}}} + (1-b_i) IMP_i^{\frac{\sigma_i^{A}-1}{\sigma_i^{A}}} \right)^{\frac{\sigma_i^{A}}{\sigma_i^{A}-1}} \quad (A7)$$

$$\max_{D,EXP} \quad PA_i \cdot A_i = PD_i \cdot (1-TD_i+SD_i-TE_i)\cdot D_i + \overline{PXM}_i \cdot EXP_i \qquad s.t. \quad A_i = \gamma_i \left(d_i D_i^{\frac{\sigma_i^{\varepsilon}+1}{\sigma_i^{\varepsilon}}} + (1-d_i) EXP_i^{\frac{\sigma_i^{\varepsilon}+1}{\sigma_i^{\varepsilon}}} \right)^{\frac{\sigma_i^{\varepsilon}}{\sigma_i^{\varepsilon}+1}} \quad (A8)$$

Consumers

$$\max_{OCIO,UA} \quad W = \left(s_{UB} OCIO^{\frac{\sigma^{UB}-1}{\sigma^{UB}}} + (1-s_{UB}) UA^{\frac{\sigma^{UB}-1}{\sigma^{UB}}} \right)^{\frac{\sigma^{UB}}{\sigma^{UB}-1}} \qquad s.t. \quad Y_{CONS} = PUA \cdot UA + w \cdot (1-SS_{CONS}) \cdot OCIO - \overline{CR} \quad (A9)$$

where $$Y_{CONS} = (1-T_{CONS})\left[r \cdot \overline{K}_{CONS} + w(1-SS_H)\cdot \overline{TIME} + \overline{TR}_{CONS} \right] \quad (A10)$$

$$\min_{AF,CFHOG} \quad PUA \cdot UA = PINV \cdot AF_{CONS} + PCF_{CONS} \cdot CF_{CONS} \qquad s.t. \quad UA = \min\left(\frac{AF_{CONS}}{s_{UA}}, \frac{CFHOG}{(1-s_{UA})} \right) \quad (A11)$$

$$\min_{EHOG,FUELOIL,OTROS} \quad PCFH \cdot CFHOG = PEH \cdot EHOG + PFUEL \cdot FUELOIL + POTROS \cdot OTROS$$

$$s.t. \quad CFHOG = \varphi_{CFH} \left(s_E EHOG^{\frac{\sigma^{CFH}-1}{\sigma^{CFH}}} + s_F FUELOIL^{\frac{\sigma^{CFH}-1}{\sigma^{CFH}}} + (1-s_{EH}-s_{RH}) OTROS^{\frac{\sigma^{CFH}-1}{\sigma^{CFH}}} \right)^{\frac{\sigma^{CFH}}{\sigma^{CFG}-1}} \quad (A12)$$

$$\min_{ELEC,EPHOG} \quad PEH \cdot EHOG = PELEC \cdot ELEC_H + PEPH \cdot EPHOG$$

$$s.t. \qquad EHOG_h = \varphi_{EH}\left(s_{EH} ELEC_H^{\frac{\sigma^{EH}-1}{\sigma^{EH}}} + (1-s_{EH}) EPHOG^{\frac{\sigma^{EH}-1}{\sigma^{EH}}} \right)^{\frac{\sigma^{EH}}{\sigma^{EH}-1}} \tag{A13}$$

$$\min_D \qquad POTROS \cdot OTROS = \sum_{i=1}^{n} PD_i \cdot D_{iH} \qquad s.t. \qquad OTROS = \prod_{i=1}^{n} D_{iH}^{SO_i} \tag{A14}$$

$$\min_{CARBON,GAS,REF} \qquad PEPH \cdot EPHOG = PCAR \cdot CARBON_H + PGAS \cdot GAS_H + PREF \cdot REF_H$$

$$s.t. \quad EPHOG = \varphi_{NEH}\left(s_C CARBON_H^{\frac{\sigma^{NEH}-1}{\sigma^{NEH}}} + s_G GAS_H^{\frac{\sigma^{NEH}-1}{\sigma^{NEH}}} + (1-s_C-s_G) REF_H^{\frac{\sigma^{NEH}-1}{\sigma^{NEH}}} \right)^{\frac{\sigma^{NEH}}{\sigma^{NEH}-1}} \tag{A15}$$

Public sector

$$\min_D \qquad CFGOB = \prod_{i=1}^{n} D_{iG}^{GOB_i} \qquad s.t. \quad Y_{GOB} = r \cdot \overline{K}_{GOB} + \overline{R}_{SOC} + R_{CONS} + \overline{TR}_{GOB} + \overline{DP} + RL + RD + RB + RE \tag{A16}$$

where $RB = \sum_{i=1}^{n} PB_i \cdot (1 - TB_i + SB_i) \cdot B_i \cdot (TB_i - SB_i)$ $\qquad RD = \sum_{i=!}^{n} PD_i \cdot (1 - TD_i + SD_i - TE_i) \cdot D_i \cdot (TD_i - SD_i)$

$RE = \sum_{i=!}^{n} PD_i \cdot (1 - TD_i + SD_i - TE_i) \cdot D_i \cdot TE_i$ $\qquad TE_i \cdot PD_i \cdot (1 - TD_i + SD - TE_i) \cdot D_i = D_i \cdot ACCISA_i$

$$RL = w \cdot \left(\sum_{i=1}^{n} SS_i \cdot L_i + SS_H \cdot \sum_{i=1}^{n} L_i \right) \qquad R_{CONS} = T_{CONS} \cdot \left[r \cdot \overline{K}_{CONS} + w(1 - SS_H) \cdot \overline{TIME} + \overline{TR}_{CONS} \right] \tag{A17}$$

Non-profit household-serving institutions (NPHSI) and corporations

$$PINV \cdot AF_{SOC} = r \cdot \overline{K}_{SOC} + \overline{TR}_{SOC} - \overline{R}_{SOC} \tag{A18}$$

$$\max_D \qquad CFISFL = \prod_{i=1}^{n} D_{iISFL}^{FL_i} \qquad s.t. \qquad Y_{ISFL} = CF_{ISFL} + PINV \cdot AF_{ISFL} \tag{A19}$$

$$Y_{ISFL} = r \cdot \overline{K}_{ISFL} + \overline{TR}_{ISFL} \tag{A20}$$

Investment and saving

$$\min_D \qquad PINV \cdot INV = \sum_{i=1}^{n} PD_i \cdot D_{iINV} \qquad s.t. \qquad INV = \min\left(\frac{D_{1INV}}{v_{1INV}}, \ldots, \frac{D_{nINV}}{v_{nINV}} \right) \tag{A21}$$

$$PINV \cdot (AF_{CONS} + AF_{SOC} + AF_{ISFL}) - \overline{DP} - PINV \cdot INV = \overline{CAPNEC} \tag{A22}$$

Foreign sector

$$\sum_{i=1}^{n} \overline{PXM}_i \cdot EXP_i + \overline{TR}_{RM} + CNR - \sum_{i=1}^{n} \overline{PXM}_i \cdot IMP_i - \overline{CR} = \overline{CAPNEC} \quad \text{where} \quad CNR = \sum_{i=1}^{n} PD_i \cdot \overline{D}_{iRM} \tag{A23}$$

Factor market

$$\overline{K}_{CONS} + \overline{K}_{GOB} + \overline{K}_{SOC} + \overline{K}_{ISFL} = \sum_{i=1}^{n} K_i \tag{A24}$$

$$TIME - OCIO = \sum_{i=1}^{n} L_i \tag{A25}$$

Environmental model

$$CO2_i = CO2C_i \cdot CARBON_{iA} + CO2P_i \cdot REF_{iA} + CO2G_i \cdot GAS_{iA} \tag{A26}$$

$$CO2_H = CO2C_H \cdot CARBON_H + CO2P_H \cdot (FUELOIL_H + REF_H) + CO2G_H \cdot GAS_H \tag{A27}$$

$$CO2 = CO2_H + \sum_{i}^{N} CO2_i \tag{A28}$$

Variables and parameters of the CGE model

Tablr A.1. Endogenous variables

PB_i	market price of each output unit B_i
B_i	national production sector i
$PKEL_i$	unit price of compound commodity *KEL*, consumed by sector i
PD_i	unit sale price (gross price) of manufactured good D_i
KEL_i	commodity made up of K, L, and E, consumed by sector i
CID_{ji}	non-energetic manufactured good j, consumed by sector i
KL_i	commodity made up of K, L, consumed by sector i
E_i	Commodity made up of different energy products, consumed by sector i
PKL_i	unit price of the compound commodity KL_i
PE_i	unit price of the compound commodity *E*
R	unit price of the capital K
w	unit price of labour *L*
L_i	labour consumed by sector i
K_i	capital consumed by sector i
SS_i	employers social security contributions paid by sector i
PEP_i	unit price EP_i
EP_i	primary energy commodities, consumed by sector i
PELEC	unit price *ELEC*
$ELEC_i$	electricity consumed by sector i
$CARBON_i$	coal consumed by sector i
PCAR	unit price of $carbon_a$
$HIDRO_i$	hydrocarbon compound commodity, consumed by sector i
PHIDRO	unit price of *HIDRO*
REF_i	refined oil products consumed by sector i
PREF	unit price of *REF*
GAS_i	natural gas consumed by sector i
PGAS	unit price of *GAS*
A_i	commodity made up of b_i plus imp_i
PXM_i	international unit price of the commodity produced by sector i
IMP_i	imports of the commodity produced by sector i
PA_i	unit cost of the armington commodity A_i
EXP_i	exports of the commodity produced by sector i
D_i	domestic demand for the commodity produced by sector i
TE_i	environmental tax on the products of sector i
W	level of welfare of the representative household
OCIO	leisure consumption
UA	commodity made up of saving commodities and services
Y_{CONS}	available income of the representative consumer
PINV	price of saving and investment
AF_{CONS}	amount of saving of the representative consumer
CF_{CONS}	commodity made up of *EHOG, FUELOIL, OTHERS*
PCF_{CONS}	price of the compound commodity CF_{cons}
PUA	unit price of *UA*
EHOG	compound commodity energy for the household
FUELOIL	refined oil products for transport
OTROS	commodity made up of D_{ih}
PEH	price of *EHOG*
PFUEL	price of *FUELOIL*
POTROS	price of *OTROS*
$ELEC_H$	electricity consumed by the representative household
EPHOG	commodity made up of CARBON, GAS, REF
D_{iH}	consumption by the household of the commodity i, except *EHOG* and *FUELOIL*
PEPH	price of *EPHOG*
REF_H	refined oil products for the households
CFGOB	commodity made up of D_{ig}
D_{iG}	public consumption of commodities and services
Y_{GOB}	public sector income available
RD	revenue obtained from tax on products
RB	revenue obtained from tax on production
RE	revenue obtained from environmental tax on CO_2 emissions
RL	revenue obtained from social security contributions

R_{CONS}	revenue obtained from tax on household income, T_{cons}
AF_{SOC}	company saving
D_{iISFL}	consumption by NPHSI of the commodity produced by sector i
CF_{ISFL}	commodity made up of D_{iISFL}
Y_{ISFL}	available income of the NPHSI
AF_{ISFL}	saving of the NPHSI
INV	compound commodity D_{iINV}
D_{iINV}	gross formation of capital in the commodity produced by sector i
$CO2_i$	CO_2 emissions made by sector i
$CO2_H$	CO_2 emissions made by households

Table A.2. Exogenous variables

TB_i	marginal rate of tax on production
SB_i	marginal rate of production subsidy
TD_i	marginal rate of tax on products of sector i
SD_i	marginal rate of subsidy for products of sector i
SS_i	marginal rate of social security contributions supported by employers of sector i
T_{CONS}	marginal rate of tax on household income
$TIME$	total time endowment of the representative consumer
TR_{CONS}	net transfers received by homes
CR	external consumption of the representative household
K_{GOB}	public sector capital endowment
K_{CONS}	household capital endowment
TR_{GOB}	net transfers received by the public sector
DP	public sector deficit
$ACCISA_i$	*ad-quantum* environmental tax on commodity D_i
K_{SOC}	company capital endowment
TR_{SOC}	net transfers received by corporations
R_{SOC}	revenue from corporate income tax
K_{ISFL}	NPHSI capital endowment
TR_{ISFL}	net transfers received by the NPHSI
$CAPNEC$	finance capacity or necessity of the economy in the face of the foreign market
D_{iRM}	domestic consumption by non-resident households of the good produced by sector i
TR_{RM}	net transfers received by the rest of the world
ϕ	marginal damage (non-utility) caused by a tonne of CO_2

Table A.3. Parameters

fixed and Leontief coefficients in the production function	fixed and Leontief coefficients in the institution consumption function
c_{ni} , $CO2C_i$, $CO2P_i$, $CO2G_i$	v_{iINV} , $CO2C_H$, $CO2P_H$, $CO2G_H$
scale parameters of the production function	scale parameters of the institution consumption function
α_i , α_{iKL} , α_{iE} , α_{iEP} , α_{iPET} , λ_i , γ_i ,	φ_{CFH} , φ_{EH} , φ_{NEH} ,
production function variable weights	institution consumption function variable weights
A_i , a_{iKL} , a_{iE} , a_{iEP} , a_{iPET} , b_i , d_i ,	S_{UB} , S_{UA} , S_E , S_F , S_{EH} , SO_i , S_C , S_G , $_{GOBi}$, $_{FLi}$,
elasticity of substitution in the production function	elasticity of substitution in the institution consumption function
σ_i^{KEL} , σ_i^{KL} , σ_i^{E} , σ_i^{EP} , σ_i^{PET} , σ_i^{A} , σ_i^{ε} ,	σ^{UB} , σ^{CFH} , σ^{EH} , σ^{NEH} ,

Elasticities.

The preferences of the representative household with relation to the different commodities and services have been gauged by using the elasticities of substitution shown in Table A.4. The elasticity of substitution between fuel for private transport, energy for the home and a commodity aggregated by the remaining commodities, σ^{CFH}, is 0.1. The elasticity of substitution between electricity and the remaining energy for the home, σ^{EH}, is 1.5. The elasticity of substitution between coal, natural gas and the remaining refined oil products which provide energy for the household, σ^{NEH}, is 1. The previous elasticities are similar to those used in Böhringer and Rutherford (1997), although lower following the principle of caution, and therefore we could say that the results obtained are somewhat conservative.

Table A.4. Elasticities of substitution in the different areas of activity

	σ_i^{KEL} (3)	σ_i^{E} (4)	σ_i^{KL} (1)	σ_i^{NE} (4)	σ_i^{PET} (4)	σ_i^{A} (1)	σ_i^{ε} (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.5. Sectors in the NAM-1995 and correspondence with the SIOT-1995

Sectors NAM-95	Description	Code SIOT 1995
AGRI	Agriculture, livestock and game, 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 SIOT codes represent the different areas of activity in the SIOT published in INE (2002a).