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Summary

Spanish emissions of carbon dioxide have grown by more than 40% in 2004 with respect to 1990. This is not compatible with the EU allocation of Kyoto-mandated CO_2 reduction, even taking into account that Spanish emissions are allowed to rise by 15% in 2010. The reasons for this situation stem from a combination of economic growth and an inefficient energy domain, coupled with a total absence of climate change policies. In this paper, we use a static general equilibrium model to assess the effects of a sudden and intense (ie, with a limited time to carry out significant abatement) CO_2 reduction by the Spanish economy. Our results show that the costs of immediate and medium-size reductions are not significant in the short run and could lead to the attaining of the EU agreed emissions level for Spain. However, delaying such action means that the degree of Spanish CO_2 emission reduction is much higher and that economic costs are far more important.

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1. Introduction

The phenomenon of climate change, with a growing scientific consensus regarding causalities and associated damage, forms one of the most serious threats that humanity is facing in the next decades. The growing concentration of greenhouse-effect gases in the atmosphere is expected to provoke very significant physical and economic effects throughout the planet (elevations in sea levels, massive precipitation, serious droughts, etc.). In particular, carbon dioxide (CO_2) is the main cause of global warming, representing around 80% of total greenhouse gas precursors.

The seriousness of the problem has propelled an important process of international agreement in the last few years for the control of these emissions, mainly through the Kyoto Protocol. This establishes the commitment of developed countries to reduce their greenhouse effect gases an average of 5% with respect to the 1990 year of reference. The refusal of the United States to ratify the Kyoto Protocol has generated serious doubts regarding its implementation, although the European Union (EU) has taken on the role of international leader in the promotion of diverse initiatives aimed at its fulfilment.

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 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 (electric generation, refinement of petroleum, the industries of iron and steel, cement, lime, glass, ceramics, brick and tile, paper and paper pulp).

In the year 2004, EU member countries must design a national plan for the allocation of rights among the different sectors so that the market may go into operation in the year 2005. Within the basic principles of national allocation plans, the necessity for additional measures is also established 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.

With respect to the situation in Spain, the distribution of emissions was beneficial in permitting Spain to increase its emissions up to a maximum of 15% in the period of 2008-2012. However, 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%, an unsustainable performance from any point of view, be it political, economic or environmental. This figure represents almost 25 percentage points of excess over the maximum limit allocated for Spain by the EU.

In this context, corrective and intense public policies are to be expected in the short term, and thus an insight into their effects seems particularly necessary. This is also necessary because Spain, given its geographical situation, is probably one of the EU countries to suffer climate change with more intensity. Thus, we analyse the effects of attaining different environmental objectives: from a reduction of 2% in the emissions of CO_2 (the annual reduction necessary in order to fulfil the Kyoto Protocol) up to a maximum of 16% (the overall objective for the 2008-2012 period).

The results obtained show that the short term cost of reducing Spanish emissions of greenhouse gases, at the annual rate of 2%, has little effect in terms of employment as well as in economic activity. However, a reduction of 16% in the short term would have a relatively considerable cost. We should conclude, therefore, that the inhibition in Spanish policy in facing the Kyoto Protocol during recent years will increase the readjustment costs for the Spanish economy. Further delays to put into practice the policy instruments for controling Spanish emissions will mean major sacrifices in the future.

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. 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), 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 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).

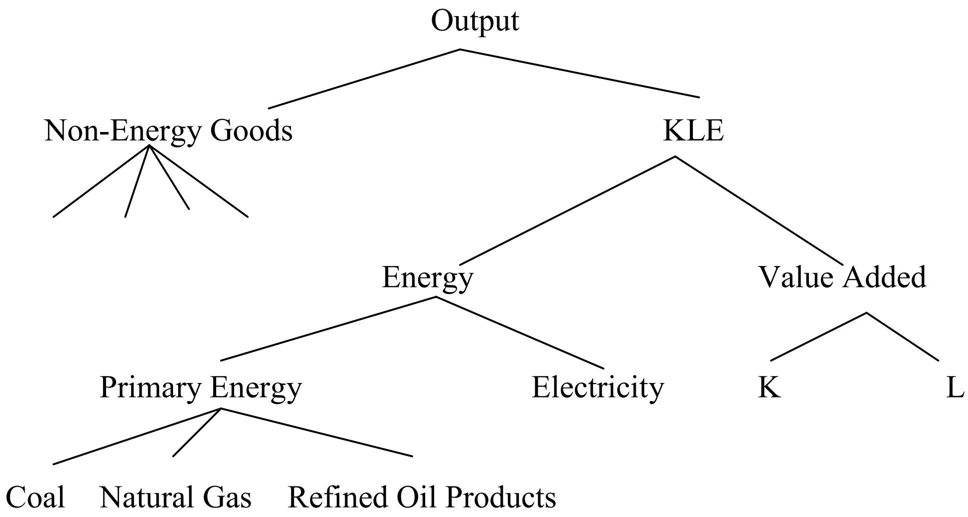
2.1 Model

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 modelled 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[1]. The energy goods are taken out from the set of intermediate inputs. They are included in a lower nest within the 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).

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

Figure 1. Production technology structure chain



As usual in AGE models[2], 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[3]. 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[4]. 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 ilustrated 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.

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[2] See Shoven and Whalley (1992).

[3] 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.

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

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

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,

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

Maximization of benefits by each sector, determined via a constant elasticity of transformation (CET) function[5], 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[6],

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

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.

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

[6] 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).

Following the breakdown of Spanish national accounts, there are five institutions in the economy[7]: a representative household, a public sector, a foreign sector, non-profit household-serving institutions (NPHSIs)[8] and corporations. In general, they receive capital income, carry out net transfers with other institutions and make savings in order to balance their budget[9]. 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[10].

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

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

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7 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).

8 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.

9 Capital endowments and transfers are exogenously determined.

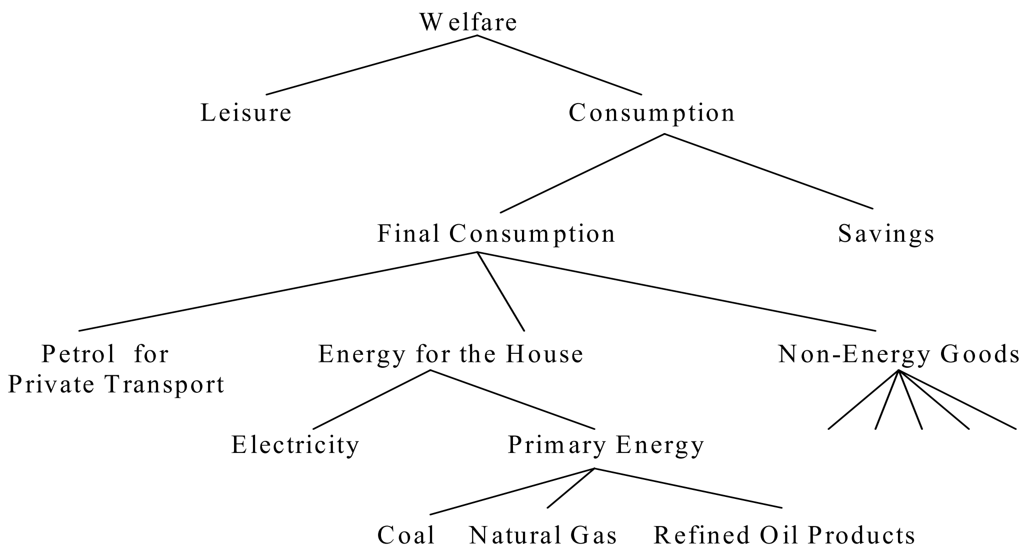
10 σ^{UB} is the elasticity of substitution and s_{UB} is the share parameter for leisure on welfare.

nominal wage and SC_H stands for social contributions, or labour taxes), plus transfers (TR), minus income taxes (T_H is the tax rate),

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

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[11], 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

[11] 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*).

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:

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

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[12], 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[13]. Certain parameters, such as elasticities of substitution, have not been calibrated, but taken from pre-existing literature[14].

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 the monetary values in the database. Following this convention, we can analyse the

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[12] 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).
[13] For a brief introduction to this methodology, see Shoven and Whalley (1992).
[14] Appendix contains a detailed description of subtitution elasticities used in the AGE.

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 July 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 a growth of emissions equal to +24% establish by the Spanish government, or equally, to reduce Spanish emissions at an annual rate of 2%.

In order to analyse the effects of fulfilling the Kyoto Protocol in Spain, we have considered different objectives; from a reduction policy of 2% in Spanish greenhouse gas emissions (equivalent to the annual rhythm of reduction necessary) to a drastic reduction equal to 16% (the overall objective in the Spanish national plan). Thus, we may explore the relationship between the intensity of the environmental objectives and its economic and social effects.

The political instrument that we have considered in order to model environmental policy is a tax on CO_2 emissions, the principal gas causing climate change. The fiscal collections generated by the tax will be returned to citizens through lump sum transfers, subject to the restriction that public expenditure should remain constant in real terms. Therefore the environmental tax (equivalent to for a market of emission permits under some theoretical conditions) has the sole intention of reducing pollutant emissions. 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 environmental tax, 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.

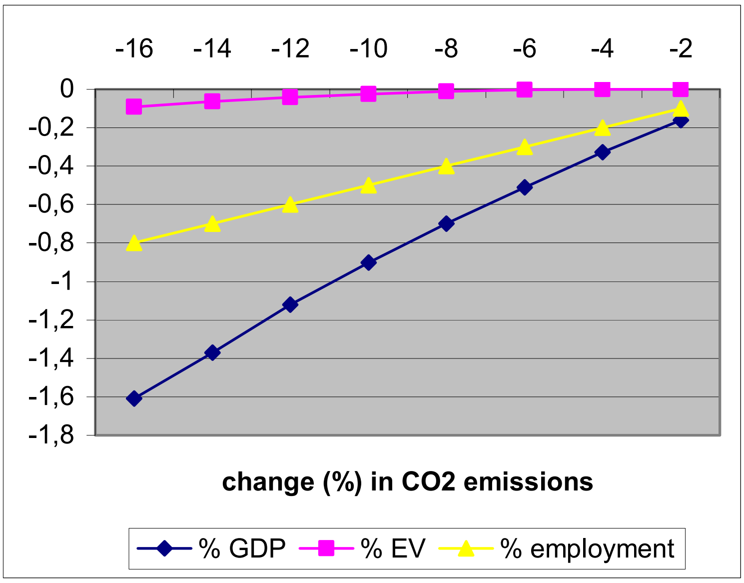
Moreover, the hybrid regulations are a politically relevant option for the European case, as we have already put forward in the introduction. Thus, McKibbin and Wilcoxen (1997) and Pizer (1997) defend the use of tradable pollution permits assigned for free by the government among the different sectors, together with additional permits at a price set beforehand by the government (equivalent to an environmental tax).

This is clearly of interest when there exists a great number of small non-mobile emitters (e.g. residential homes, 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 costs of transaction 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 emissions of 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.

3.2. Results

In figure 3, we present the effects of the different simulated policies on the Gross Domestic Product (GDP), employment and social welfare. When the short-term environmental objectives pursued by the government are modest, with reductions in CO_2 emissions of less than 6%, small drops in the GDP of less than 0.5% will be produced. If we increase the reduction of emissions by an amount around 10-12%, the effects on GDP are significant, with drops of approximately 1%. Finally, the environmental objective proposed by the government for the 2008-2012 period, which is to say, a drop in emissions of 16%, could, in the short term, provoke significant effects on the economic activity equivalent to a loss of 1.6% of the GDP.

Figure 3. Reduction in Spanish CO_2 emissions and its effects on GDP, employment and social welfare. These are percentage changes (%) as compared to 1995.



Source: own calculations. EV stands for the hicksian equivalent variation on social welfare.

There exists, therefore, a slight convex relationship between the reduction of emissions and the costs in terms of GDP. Small reductions in emissions are easily reachable, but these become more costly as we toughen the objectives of the environmental policy. Previous results highlight the opportunity costs of delaying the introduction of instruments for the control of Spanish CO_2 emissions. The shorter is the period of time to reach a certain environmental objective, the higher the cost to the economy. These results are consistent with the empirical evidence analyzed by different works, such as those of Grubb et al (1993), Clarke et al (1996) or Dean and Hoeller (1992).

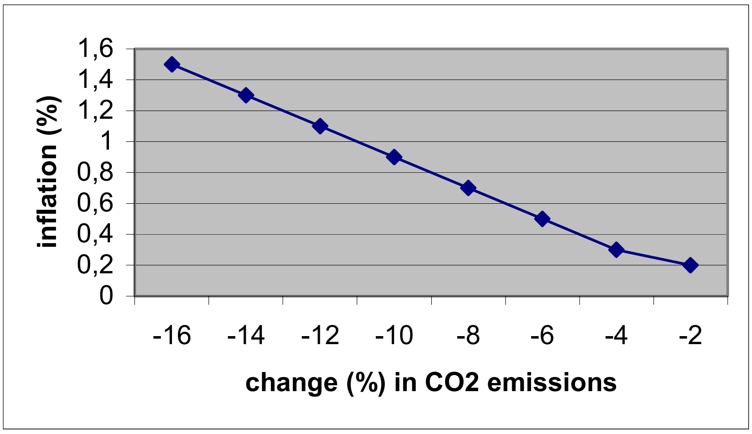
The adverse effects of the environmental policy on the economic activity translate into a drop in the demand for labour, as shown in figure 3. The effects on employment, estimated through the model, were the results of two opposing economic forces. Firstly, the environmental objectives represent an additional cost for the different sectors, characterised by the tax rate coming from the environmental regulation. Said extraordinary cost would have a negative effect on activity and therefore, on the demand for labour. Secondly, the environmental regulation encourages the demand of labour. At the firm level there is a substitution effect between dirtier and cleaner energies, but also between energy and other productive factors such as work. At the macroeconomic level, the substitution effects can provoke sectorial changes in the structure of the economy, reducing the weight of the sectors that are intensive in energy in favor of labour intensive ones.

The equilibrium between both opposite forces makes the drop in the demand for labour less intensive than the effects on economic activity. Thus, a drop in CO_2 emissions of less than 6% produces a loss of employment of small significance and inferior to 0.3%. It can also be observed that the negative effect on employment grows with lesser intensity than it does on the GDP. As a result, reducing the Spanish emissions of CO_2 by 16% would produce a contraction in employment of 0.8%, approximately half the effect on the GDP.

Our results contrast with those obtained by Manresa and Sancho (2004). These authors estimate that a reduction of approximately 3.5% in Spanish CO_2 emissions would cause a 17% increase in the unemployment figures of 1990. The impact on the labour market is considerably more negative than that estimated in our work. However, both results are difficult to compare, since Manresa and Sancho (2004) take into account a curve or function that relates salaries and unemployment instead of a competitive labour market.

Surprisingly, the effects of the simulated environmental policies on the Consumer Price Index (CPI) are similar to the effects on GDP, although they present the opposite sign logically. The changes in the estimated prices are relative with respect to the *numeraire* (international prices in our model), and are presented in figure 4. Relatively small reductions in pollution emissions (lower than 6%) have effects of little significance on inflation (increases of prices less than 0.5%). In extreme cases, a 16% reduction in emissions would cause an increase of 1.5% in consumer prices.

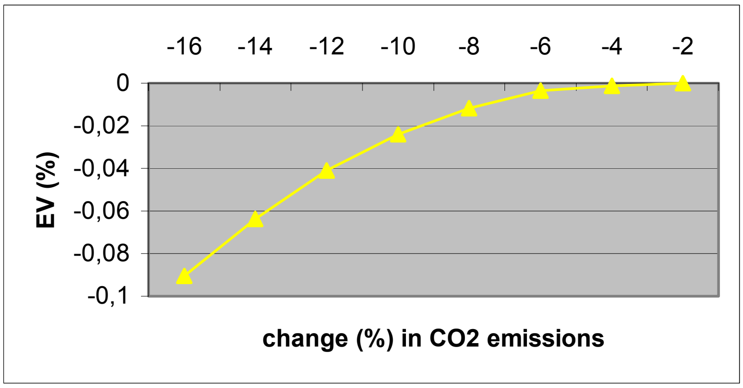
Figure 4. Percentage changes (%) in the Consumer Price Index.



Source: own calculations. Consumer Price Index with respect to the numeraire (international prices).

Unlike the variables studied previously, there exists a strong non-linear relationship between the reduction in emissions and its effects on social welfare (excluding environmental effects). The changes in social welfare are measured in terms of equivalent variations, as it is usual in the literature (Shoven and Whalley, 1992). Said relationship is convex, as shown in figure 5. This is to say, the negative effects on social welfare grow more than proportionally than the changes in CO_2 emissions. In any case, the effects are of little significance. In this way, a reduction of 16% in CO_2 emissions would have a cost of only 0.1% in terms of social welfare. We should not forget that the fiscal revenues obtained by the environmental tax are returned to citizens through lump sum transfers which may reduce the impact of the public policy on consumption. Manresa and Sancho (2004) also obtain results of little significance on welfare when simulating a reduction of approximately 3.5% in Spanish CO_2 emissions. Similar results also have been obtained by Bohringer, Ferris and Rutherford (1997) for a reduction of 20% in Spanish CO_2 emissions.

Figure 5. Percentage changes (%) in e CO_2 emissions and social welfare with respect to the benchmark (1995).

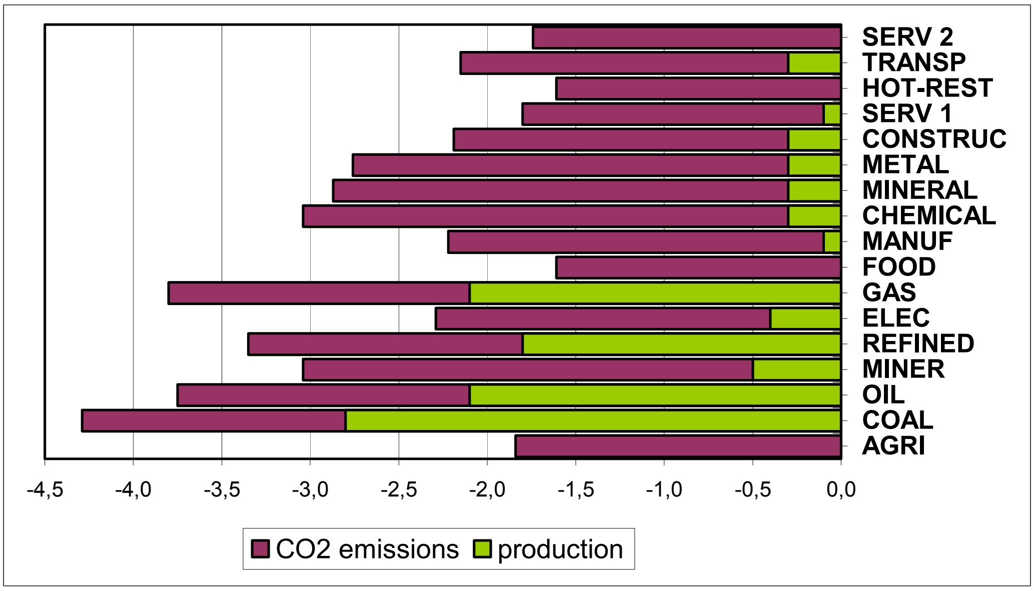


Source: own calculations. EV stands for the hicksian equivalent variation on social welfare.

The costs for Spain in fulfilling the Kyoto terms could be smaller when political action is articulated through "green" fiscal reforms. Using the fiscal income collected by the environmental tax in order to reduce other distorted taxes (generally, income taxes) generates a weak double dividend (Bovenberg and Goulder, 2002), which permits the reduction of the costs of environmental regulation. This is shown by diverse empirical works, such as those of Carraro, Galeotti and Gallo (1996), Capros et al. (1995) or Gómez and Kverndokk (2002). All of these have analysed the effects of a "green" fiscal reform in Spain, with reduction in social contribution. In all cases, the effects on GDP were of little significance. The previous works also estimate effects of little significance on employment. However, Barker and Köhler (1998) estimate that a reduction in Spanish emissions of CO_2, through a "green" fiscal reform with a reduction in social contributions, could increase employment by 1.2%. Contrary to the previous results, Barbiker et al. (2001) estimate that the costs of Kyoto for Spain, in terms of social welfare, will be significant.

In order to study the sectorial effects of the environmental policy, we have analysed a policy of 2% reduction in CO_2 emissions, a reasonable short term objective. 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 6. The most significant effects on production arise in primary energy sectors, with drops that oscillate between 2.8% for the coal sector and 2.1% for the refined petroleum sector.

Figure 6. Sectorial effects on production and emissions from a 2% reduction in CO_2.



Source: own calculations.

The electric sector, however, experiences a slight drop equal to 0.4%, owing to two fundamental reasons. The classical thermal power utilities (coal, fueloil, gas) represent only 40% of the total electricity generation in Spain. In other words, only 40% of production from the electric sector will be indirectly levied by the environmental tax. 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.

The remaining non-energy sectors experienced not very significant effects on their activity, ranging from a drop of 0.3% in diverse products to a null effect on agriculture and fishing, food, hotel and catering businesses and certain services (education, health, leisure and culture, etc.). The previous results are reasonable if we bear in mind that electricity represents approximately 70% of the final consumption of energy in Spain.

Reduction of emissions is distributed in a less heterogeneous way than the changes in the level of activity. In general, all the economic sectors reduce their emissions in a significant way and by an amount over 1%. As we expected, the drops in the energy sectors, over 3% except in electricity (2.3%), stand out. Other sectors such as diverse products (chemical, mineral and metallic products), also achieve significantly large reductions in their emissions, of close to 3%.

4. Conclusions

Spanish emissions of greenhouse gases have followed a path of strong growth during recent years. This behaviour is incompatible with the objectives of Kyoto for Spain, and in addition, it reflects an inefficiency and a very dependent energy system. In accordance with the internal distribution of the EU, in order to fulfil the Kyoto Protocol, Spain should reduce it current greenhouse gas emissions 16% in the period from 2008 to 2012, therefore having an average annual reduction of 2%.

The objective of this work is to analyse the costs for Spain of fulfilling the European Community objectives of reducing emissions through the introduction of a tax on CO_2 emissions. 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.

The results obtained show that the costs of reaching the objects set by the EU for Spain are of little significance if the measures of environmental policy are taken within a sufficient amount of time in advance. The objective of the government to reduce the emissions of greenhouse gases at an annual rate of 2% would result in a drop equal to 0.2% in the GDP as a consequence, with this figure being even lower in terms of employment. The effects on social welfare would be null.

The energy sectors are logically the most affected by environmental regulation, with drops in activity of close to 2%. The consequences on the electric sector are, however, very small, owing to the effects of substitution which favour the consumption of this energy. The losses in activity in the remaining non-energy sectors are of little significance.

Nevertheless, if the Spanish government persists with a policy of inhibition in the short term, of “wait and see”, the consequences for Spain could be very negative. Given the limited temporary margin that the politicians have left by the three previous governments, an extreme situation could arise of a reduction of 16% in emissions in the short term in the best case scenario (if the emissions maintain their current level, something that is not probable). In this context, the economic and social cost would be significant, with a loss of over 1% in GDP.

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 greenhouse gas emissions. Obviously, these should be introduced through cost-effective instruments of environmental policy; for example, through a hybrid system of taxes on some sectors and institutions along with an emission commerce system for some spacific industrial sectors as the european.

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Appendix

Production functions in the AGE

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

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

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

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

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

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

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

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

Consumer functions in the AGE

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

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

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

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

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

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

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 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 Symmetric Input Output Table (SIOT) codes represent the different areas of activity published in INE (2002a).

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