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Economic and environmental effects of the CO_2 taxation: an input-output analysis for Spain

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Abstract

CO_2 emissions induced by human activities are the major cause of climate change; hence, strong environmental policy that limits the growing dependence on fossil fuel is indispensable. Tradable permits and environmental taxes are the usual tools used in CO_2 reduction strategies. Such economic tools provide incentives to polluting industries to reduce their emissions through market signals. The aim of this work is to investigate the direct and indirect effects of an environmental tax on Spanish products and services. We apply an environmentally extended input-output (EIO) model to identify CO_2 emission intensities of products and services and, accordingly, we estimate the tax proportional to these intensities. The short-term price effects are analyzed using an input-output price model. The effect of tax introduction on consumption prices and its influence on consumers' welfare are determined. We also quantify the environmental impacts of such taxation in terms of the reduction in CO_2 emissions. The results, based on the Spanish economy for the year 2007, show that sectors with relatively poor environmental profile are subjected to high environmental tax rates. And consequently, applying a CO_2 tax on these sectors, increases production prices and induces a slight increase in consumer price index and a decrease in private welfare. The revenue from the tax could be used to counter balance the negative effects on social welfare and also to stimulate the increase of renewable energy shares in the most impacting sectors. Finally, our analysis highlights that the environmental and economic goals cannot be met at the same time with the environmental taxation and this shows the necessity of finding other (complementary or alternative) measures to ensure both the economic and ecological efficiencies.

Keywords: CO_2 emissions; environmental tax; input-output model, effects of environmental taxation

1 Introduction

Recently, concern about climate change has increased as there are overwhelming scientific evidences that the earth is warming up, which may result in a devastating long term effects (IPPC 2007; Stern et al. 2006). Human activities are believed to be the major cause of greenhouse effects and no efforts in emissions reduction will end up in unpredictable consequences. Hence, there is an urgent need for actions on climate change in order to avert its worst impacts and outweigh its potential cost (Stern et al. 2006). This has opened up a door for different environmental measures to be considered in the policy agenda. Environmental taxes and tradable permits are the economic instruments which mostly have been considered and implemented in order to control anthropogenic CO_2 emissions. Such economic tools can play a crucial role in achieving climate change mitigation in a more cost-effective manner than regulatory based approaches, as they equalise marginal abatement costs of industries (Fullerton et al, 2010; Jaffe and Stavins, 1995).

Environmental taxes have been put into practice in the developed world, especially in the European Union (EU) since the nineties century (Ekins 1999). A number of EU countries have implemented a wide range of environmental taxation such as taxes on motor fuels and motor vehicles, natural gas, coal, electricity, plastic bags, landfill wastes, batteries, pesticides, fertilizers, sulfur dioxide (SO_2) and CO_2 to cite a few. More recently the EU has also established a "cap-and-trade" scheme under EU-Emissions-Trading System (EU ETS) to limiting GHG emissions to a 20% less than the 1990 level by the year 2020.

This paper aims at investigating the potential impact of CO_2 taxation in the Spanish economy. It deals with both the economic impacts of the taxation (i.e. its effects on production prices, private welfare and public taxation revenues) and the environmental effects (i.e. the reduction in CO_2 emissions). We use an environmentally-extended input-output analysis (EIO) as a methodological tool to quantify CO_2 emission intensities, which are used as a base for defining the environmental tax rates. The introduction of the tax would increase production costs in proportion to the emission intensities in each sector.

The Leontief price model, firstly proposed by Leontief (1946) in an attempt to assess the US economy, can be used to capture the direct and indirect price effects of the new taxation. Manresa et al. (1988) used a generalized input-output model to evaluate the effects of the new indirect taxes in Spain after joining the European Economic Community. McKean and Taylor (1991) utilized the price model to study how the alteration in import prices and sectoral inputs influence internal cost of production in the Pakistan economy. An extended version of the price model was also implemented by

Boratyński (2002) to analyse the role of indirect taxes in the Polish economy. For the Spanish economy, Labandeira and Labeaga (2002) used the price model to study the price effect of hypothetical carbon taxes levied on fossil fuel consumption based on sectoral energy-related CO_2 intensities for the Spanish economy in 1992. Llop and Manresa (2004) studied the influence of factor prices and imports for the Catalan economy. More recently, Llop (2008) used price model to evaluate the changes in prices due to new water policy scenarios in Spain, whereas Llop and Pié (2008) analysed the consequences of a tax on energy uses in the Catalan economy.

This paper applies the Leontief price model to examine the direct and indirect effects on production prices, induced from the environmental taxation. It evaluates how production prices would respond to the implementation of the new environmental tax and consequently, the effects on individual consumer's welfare and on public revenues. We also calculate the environmental consequences of the environmental taxation, measured in terms of the reduction in CO_2 emissions. All these variables allow us to reflect not only the economic impacts of the simulations but also the environmental impacts. Three sectors, namely: *Production and distribution of electricity*; *Manufacture of gas, distribution of gaseous fuels through mains steam and hot water supply;* and *Manufacture of non-metallic minerals* are selected to run the price model simulation. The selection is based on the result of the EIO analysis and responds to the sectors with the highest emission intensities.

The paper is organized as follows. The second section explains the methodological framework used. The third section presents the empirical results. Finally, the last section concludes.

2 Methodology

The environmental tax is based on the CO_2 emissions of products and services of the Spanish economy. EIO analysis is a top-down approach used to account for resource consumption and environmental loads, and is based on the information of input-output tables (Miller and Blair 2009; Matthews et al. 2008; Suh and Huppes 2005). The approach uses generic data at national level to evaluate the emission intensities of each industry (vector ***m*** in equation (1)). The EIO model, which is derived from the structure of the input-output table, is symmetric in nature as it is based on a one-to-one industry and product relationship, i.e. each industry is assumed to produce only one product and each product is produced by only one industry. It is represented in matrix notation as follows:

$$m = e^{'}(I - A)^{-1} \tag{1}$$

I is ***n-by-n*** identity matrix, where ***n*** stands for number of industries in the economy. ***A*** is ***n-by-n*** matrix of technical coefficients, whose element a_{ij} measures the flow from industry ***i*** required to produce €1 output of industry ***j***. ***e'*** is a row vector of industrial emissions in which each element e_i represents the amount of CO_2 emissions released to produce €1 output of industry ***i***.

EIO model has important features that allow the estimation of CO_2 emission intensities of products and services. One of these features is that EIO maps all the interactions between the industries in a given economy and hence, it allows the estimation of life cycle emissions of products and services. Another feature is its ability to explicitly assess both direct and indirect emissions. All of this covers the entire emissions associated with the final demand of products and services.

The environmental tax on production, $\boldsymbol{\varepsilon}$, is estimated by multiplying the emissions intensity of each sector by a carbon price $\boldsymbol{\varphi}$, expressed in €/ton of CO_2[i].

$$\varepsilon = \varphi\, e'\,(I - A)^{-1} \tag{2}$$

Here, the CO_2 tradable permit price of EU Emissions Trade System (EU ETS) is considered as equivalent to carbon price. The EU ETS was launched in 2005 with the target of reducing GHG emissions at least a 20% below the 1990 level by the year 2020. It works on the “cap and trade” principle. The EU ETS established a uniform carbon price for selected industries across the EU, which can be seen as an environmental charge for each industry and can be regarded as equivalent to an environmental tax. The environmental tax rate on products and services based on their CO_2 emission intensities could also be considered to achieve the same reduction target as the EU ETS scheme.

Once the environmental tax for each product and service is estimated, then the impacts on the economy are analysed using the Leontief price model. The price model is formulated on the foundation of two basic assumptions: fixed proportions, under the assumption of constant returns-to-scale, and no consumer’s utility functions. The former assumption is usually made in EIO models in which each industry produces a unique product and there is a fixed relationship between each sector’s output and all its inputs. This assumption ignores the possibility of economies of scale in the production system. The later totally ignores the final demand relationship in the determination of prices.

Assuming that the sectoral prices are equal to the average cost of production, the normalized unitary price of output in each sector ***j***, $\boldsymbol{p_j}$, can be expressed as the total cost of intermediate inputs and total value-added expenditure as follows (Llop 2008):

$$p_j = (1+\tau_j)\left[\sum_{i=1}^{73} p_i a_{ij} + (1+s_j)wl_j + rk_j + (1+t_j^m)p_j^m m_j\right] \quad (3)$$

where $\boldsymbol{\tau_j}$ is the ad-valorem tax on production in net terms, $\boldsymbol{a_{ij}}$ are the input-output technical coefficients, $\boldsymbol{s_j}$ is the tax rate of social Security paid by sector ***j***, ***w*** is the price of labour (wage), $\boldsymbol{l_j}$ is the labour coefficient, ***r*** is the price of capital, $\boldsymbol{k_j}$ is the coefficient of capital, $\boldsymbol{t_j^m}$ is the ad-valorem rate of the imports in sector ***j***, $\boldsymbol{p_j^m}$ is the price of imports and $\boldsymbol{m_j}$ is the import coefficient.

The impact of environmental tax rate (ε_j) on the cost structure of sector ***j*** could be evaluated using the following equation.

$$p_j^\varepsilon = (1+\tau_j)(1+\varepsilon_j)\left[\sum_{i=1}^{73} p_i a_{ij} + (1+s_j)wl_j + rk_j + (1+t_j^m)p_j^m m_j\right] \quad (4)$$

The above production price can be expressed in matrix form as:

$$p^\varepsilon = (I - A^*)^{-1} b \quad (5)$$

where $\boldsymbol{A^*}$ is the new technical coefficients matrix that incorporates both the ad-valorem and environmental taxes and ***b*** is the vector of value added per unit of output, which includes the capital, labour and import variables.

The impact of the environmental tax can also be analysed in terms of changes in consumer's price index and in private welfare. Consumer's price index examines the weighted average prices of a basket of goods consumed by households and it is calculated by using a normalized basket of goods, which define the weights of the final prices:

$$p_c = \sum_{j=1}^{73} p_j \alpha_j , \tag{6}$$

where p_j is the production price of sector j and α_j stands for the share of final goods from sector j as a ratio of the total goods consumed in the economy.

The impact of the tax on the private real income, that could be refereed as change in consumer's welfare, can be approximated using the following expression:

$$\Delta W = W - W^{\varepsilon} = \sum_{j=1}^{73} p_j \, C_j - \sum_{j=1}^{73} p_j^{\varepsilon} C_j \tag{7}$$

where p_j and p_j^{ε} are the consumption prices before and after the introduction of the environmental tax respectively, C_j is the consumption of goods of sector j by households. Any positive value in the change of welfare corresponds to a situation in which there is a consumer's benefit. A negative result represents a worse situation for consumers in which there is a reduction in individual consumer's welfare.

Changes in sectoral production prices induced by the tax could also be reflected in the total production output. Such effects can be evaluated by assuming that the monetary values of sectoral output before and after the introduction of the tax are kept constant at the original levels. Therefore, the new sectoral output of sector ***j*** after the environmental tax (X_j^{ε}) can be calculated as:

$$X_j^{\varepsilon} = \frac{p_j X_j}{p_j^{\varepsilon}} \tag{8}$$

and taking into account that prices in the reference equilibrium are unitary (i. e. $p_j = 1$). Using the proportionality assumption of the input-output approach, each sector's total CO_2 emissions are directly linked to the total output of that sector. Therefore, we can approximate the new sectoral emissions that would be released after the introduction of the tax:

$$E_j^{\varepsilon} = eX_j^{\varepsilon} \tag{9}$$

Finally, the total public revenues (*R*) that could be raised from the tax would be evaluated as:

$$R = \sum_{j=1}^{73} \varepsilon_j p_j^{\varepsilon} X_j^{\varepsilon} \tag{10}$$

3 Results and discussion

The empirical application is based on the following data sources:

- The data on CO_2 emissions were obtained from the Satellite Atmospheric Emissions Accounts for Spain provided by the Spanish Institute of Statistics (INE) for the year 2007 (INE 2010a). The emission data were aggregated into 29 industries. Sectoral total outputs were used to disaggregate the emissions data into 73 sectors.
- The economic data on sectoral transactions come from the Supply and Use tables published by the Spanish Institute of Statistics for the same year 2007 (INE

2010b). The Supply and Use tables are disaggregated into 73 industries and 118 commodities. They were used to derive the industry-by-industry total requirement matrix necessary in equation (1).

- The data on the ad-valorem tax ***t*** on industries were calculated from the Use table by dividing the taxes less subsidies on products by the total sectoral uses in basic prices.

EIO allows for assessing the environmental taxes based on CO_2 emission intensities for all the products and services within the Spanish economy. According to the source data from the European Climate Exchange (EEA 2009), the average EU ETS permit price for the year 2007 was 20 €/ton. This price was used as a benchmark CO_2 price applied in order to estimate the environmental tax rate associated with each sector's CO_2 emission intensity. Figure 1 shows the qualitative analysis on the frequency distribution of sectoral tax rate when a price of 20€ per ton of CO_2 is applied. As displayed in the graph, around 66% of the Spanish production sectors would experience an environmental tax rate of less than 1% and only 3% of sectors would exhibit a tax rate higher or equal to 5%. Almost 84% of sectors experience tax rates smaller than 2%.

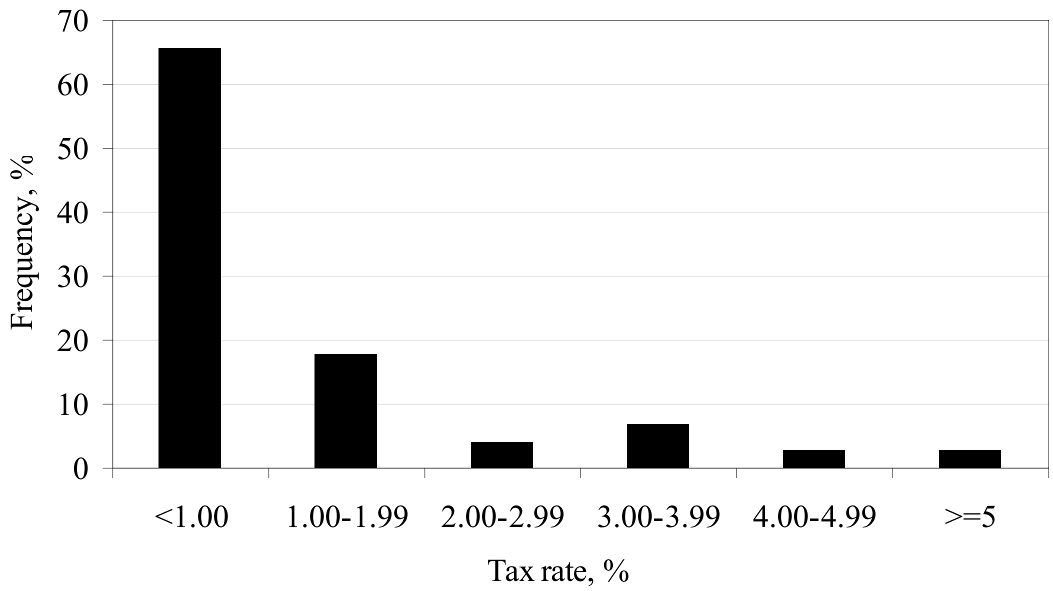

Figure 1. Frequency distribution of environmental tax rate of sectors in the economy.

Figure 2 summarizes the top 25 sectors that would be subjected to the highest environmental tax. The highest environmental tax would be levied on *Production and distribution of electricity*, which exhibits a 6.08% tax rate. This is due to its poor environmental profile, in which the share of renewable energy source in the national electricity mix is significantly low, only 20%. Its production is mainly relayed on inputs from highly polluting sectors such as *Manufacture of gas, distribution of gaseous fuels through mains steam and hot water supply; Manufacture of coke, refined petroleum products and nuclear fuel* and *Mining of coal and lignite, extraction of peat*. According to the data from Secretaria de Estado de Energia (SEE) (2007), energy from coal represents the largest share, which accounts for 24% of the total mix followed by combined cycle and nuclear power, representing 22 and 18% respectively. The share of renewable energy source in the national mix is only 19%. However, in recent years, the Spanish government has been taking a considerable effort in moving the sector a step forward to get a environmentally cleaner electricity, by increasing the share of renewable energy sources in the national mix. The recent data from the SEE (2010) shows that renewable energy has contributed by 33.4% in the total mix in 2010, with a 76% of increase compared with 2007.

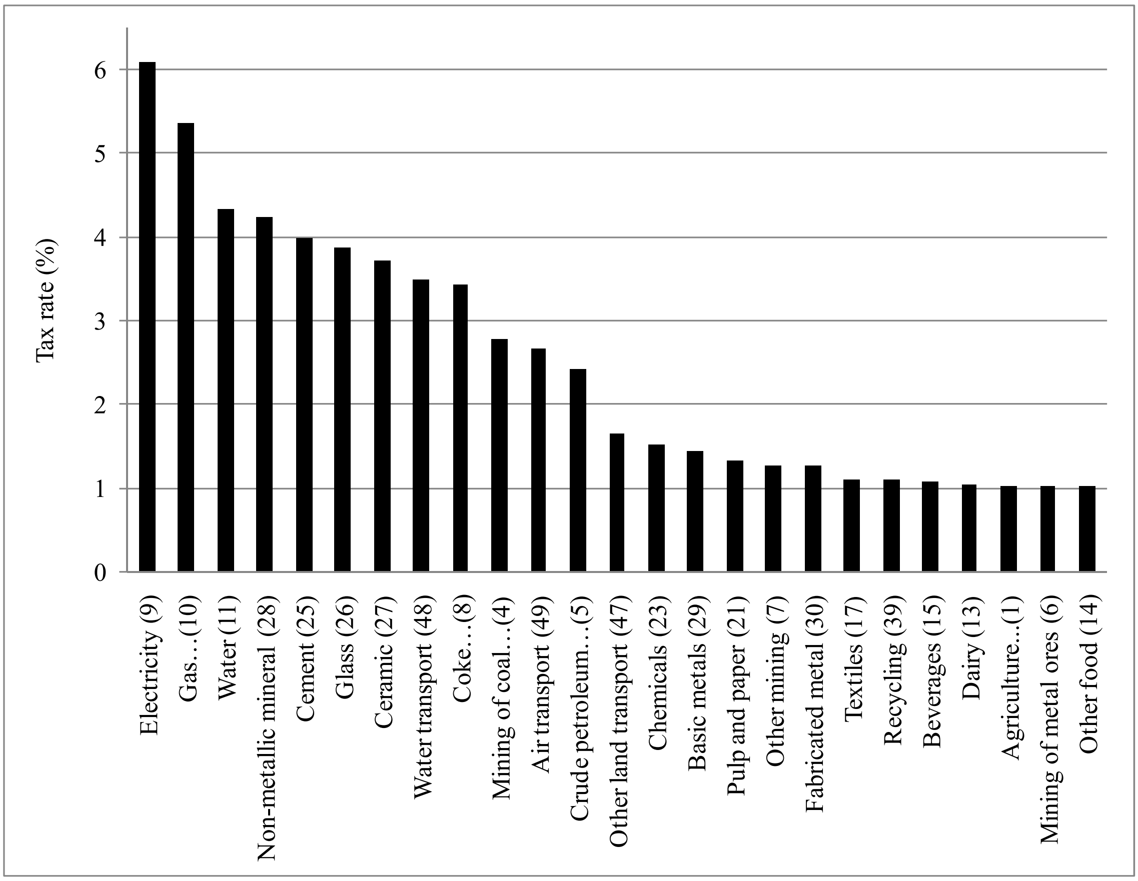

Figure 2. CO_2 emissions based environmental tax for the top 25 polluting industries

Manufacture of gas; distribution of gaseous fuels through mains, steam and hot water supply and *Manufacture of other non-metallic minerals* are also subjected to high environmental taxes, 5.36% and 4.31% respectively. The gas manufacturing industry covers a wide range of operations such as exploration of gas, production, storage and distribution to end-users. The relatively high environmental tax of this sector is due to a considerable amount of emissions: one is from the direct combustion of fossil fuels used as energy source in process equipment and facilities in the industries, and the other is from equipment leaks and vented emissions.

The high emission intensity (and high environmental tax) of *Manufacture of other non-metallic minerals* is due to high energy (heat) and chemical requirements in the production process. This sector transforms mined or quarried non-metallic minerals such as sand, gravel, stone and clay into a wide range of products, for instance, concrete, mortar and blocks both for intermediate and final consumption. Energy intensive processes like grinding, mixing, cutting and shaping are among the important processes responsible for the highest CO_2 sectoral emission intensities.

As expected, high energy intensive manufacturing sectors, for example *Cement, lime and plaster*; *Glass and glass products* and *Ceramic products*, are also among the most affected sectors from the introduction of an environmental tax. These sectors are known for comprising high energy demanding processes. For instance, the cement production sector accounts for 6.3 to 7.2% of global industrial energy use, with an average of primary energy intensity of 4.4 gigajoules per tonne of production (IEA 2007). High emissions of this sector are mainly due to the consumption of fossil fuel and the calcinations of limestone in cement production.

The introduction of an environmental tax favours the less polluting sectors while it increases the production prices of goods and services in sectors with poor environmental profiles. The effect of the environmental tax is reflected on the production cost trough the market signals. Even though the sector itself on which tax is levied would be the most affected one, other sectors are also indirectly affected as the result of sectoral interactions. This can be captured with the application of a Leontief price model. To illustrate up how the price model works, we have considered three cases: an environmental tax imposed on *Production and distribution electricity;* on *Manufacture of gas, distribution of gaseous fuels through mains, steam and hot water supply* and on *Manufacture of other non-metallic minerals*. The selection is based on the CO_2 emission intensity results from the EIO model. As shown in figure 2, these are the three activities that experienced the highest environmental tax rates.

In what follows, we present the price effects of the environmental taxation when it is applied to each of the selected sectors separately. A 6.1% environmental tax on *Production and distribution of electricity* caused a general increase in production prices of all sectors in the economy. As can be seen from figure 3, the highest price raise is observed in the sector itself, which exhibits a production price increase of up to 7.6%. Particular sectors such as *Transport via railways; Manufacture of cement, lime and plaster; Other mining and quarrying; Manufacture of other non-metallic mineral products*; *Mining of coal and lignite, extraction of peat*; and *Manufacture of pulp, paper and paper products* are among the most sensitive sectors, and are subjected to relatively high price increases when environmental tax is introduced on the *Production and distribution of electricity*. These sectors are well known for their high electricity requirements in order to produce their outputs.

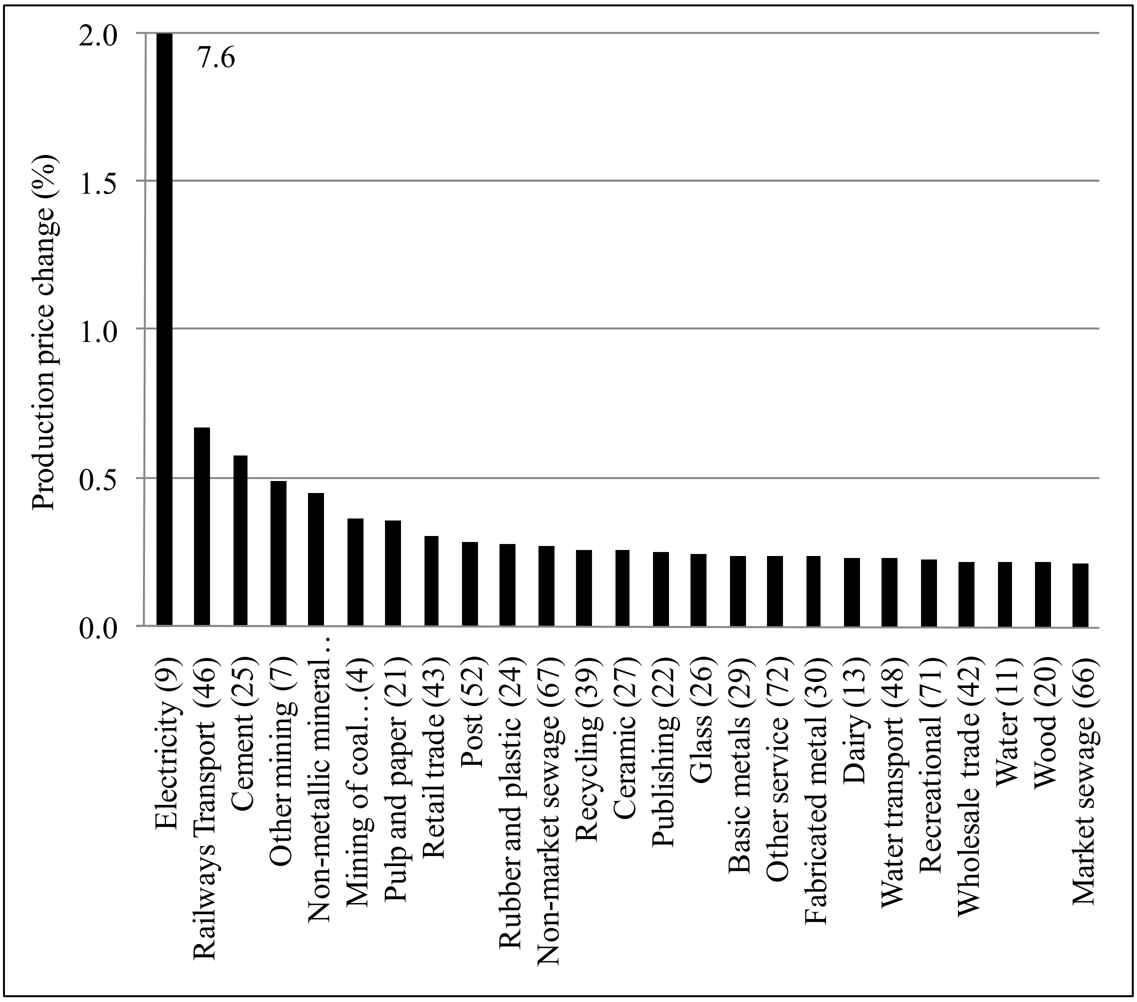

Figure 3. Changes in production prices (%) of an environmental tax (6.1%) on *Production and distribution of electricity.*

Figure 4 shows that a 5.3% environmental tax rate on *Manufacture of gas, distribution of gaseous fuels through mains steam and hot water supply* increases its production price by 5.4%. Though this is the highest impact, *Production and distribution of electricity* and *Manufacture of ceramic products* are also among the sectors affected, showing a price rise by 0.8% and 0.3% respectively. The effect on the other sectors is not significant.

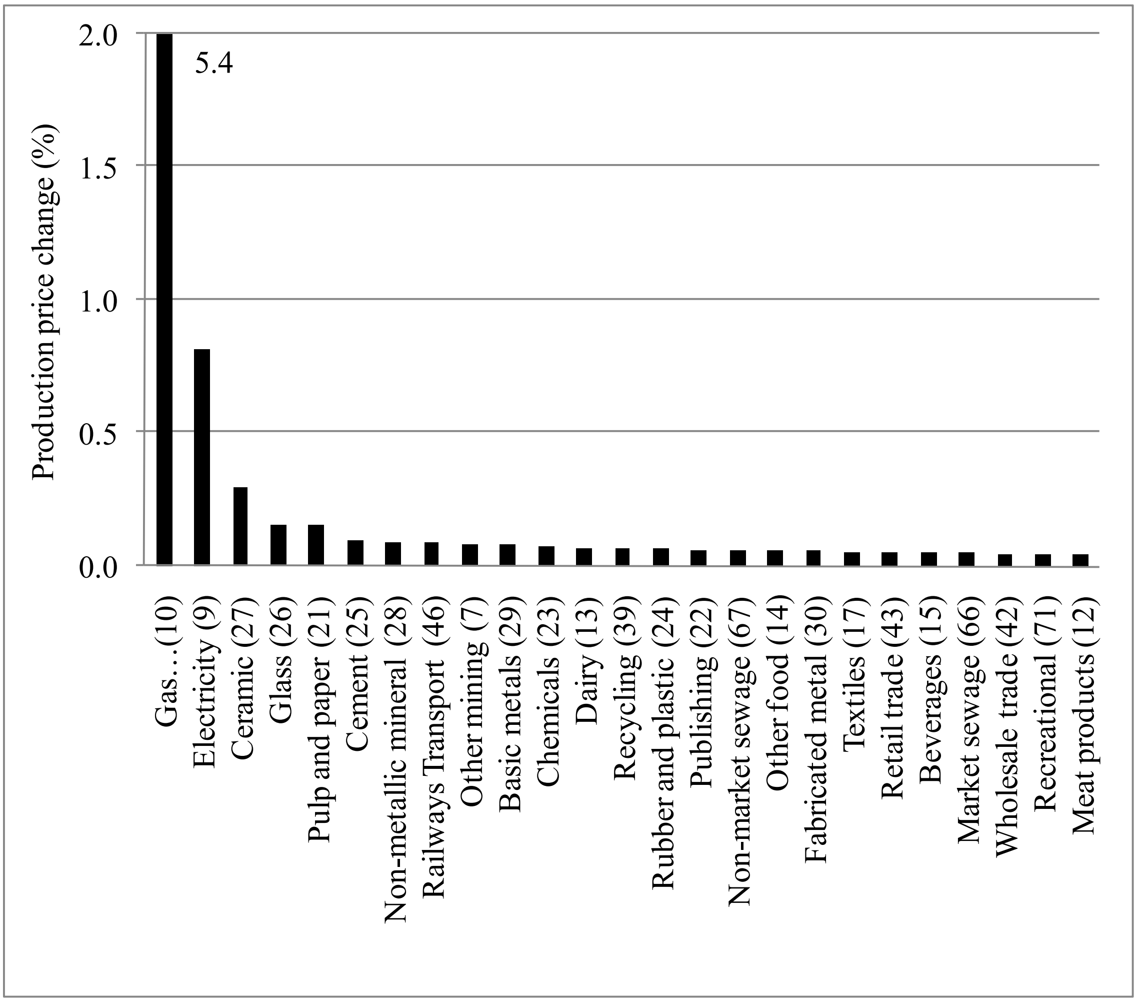

Figure 4. Changes in production prices (%) of an environmental tax (5.3%) on *Manufacture of gas, distribution of gaseous fuels through mains, steam and hot water supply* sector.

A 4.3% tax on *Manufactures of other non-metallic minerals* is shown in figure 5. As described, *Construction* is relatively sensitive to changes in production prices of *Manufacture of other non-metallic minerals.* Though not so high, sectors such as *Manufacture of Cement, lime and plaster*; *Manufacture of glass and glass products* and *Manufacture of ceramic products* are also sensitive to the price increase in *Manufacturer of other non-metallic mineral*. The effect on the other sectors is negligible, as can be seen in figure 5.

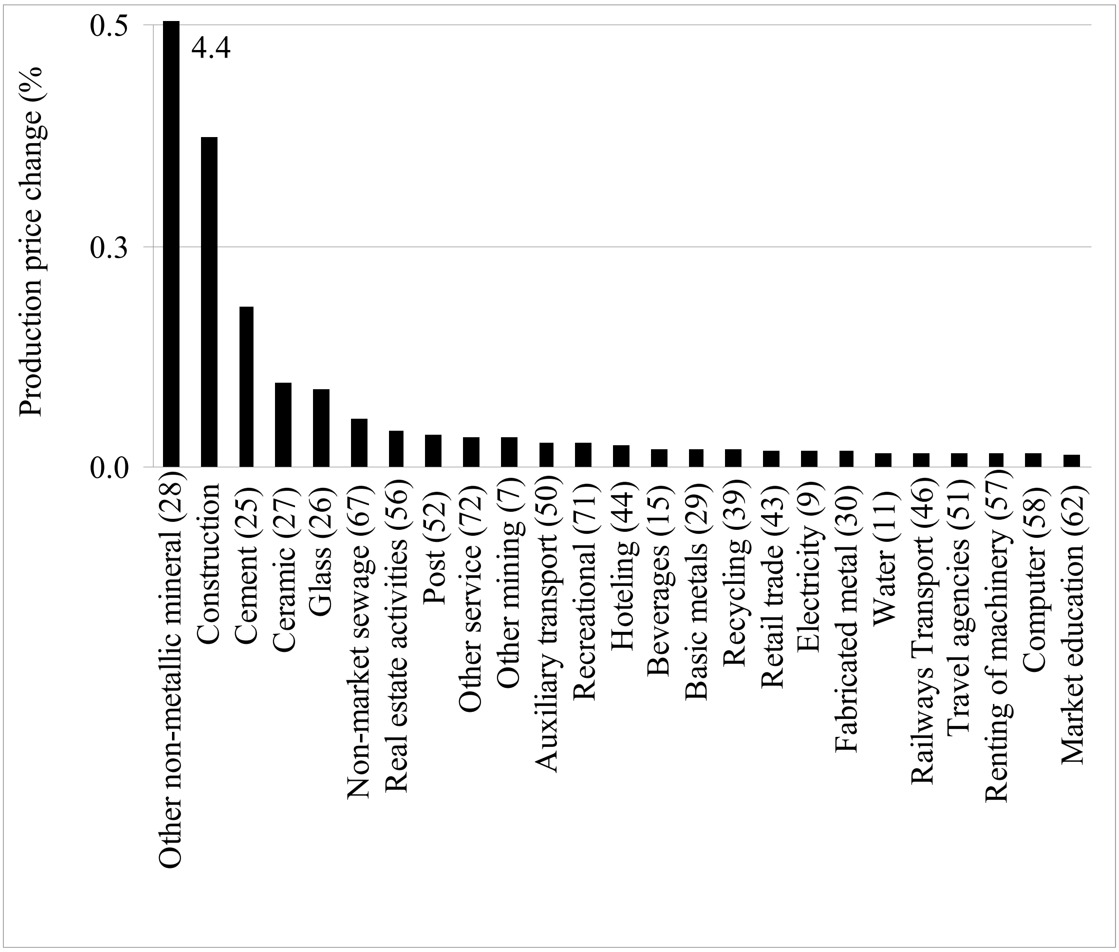

Figure 5. Changes in production prices (%) of an environmental tax (4.3%) on *Manufacturer of other non-metallic mineral.*

We also estimated the potential effects of the environmental tax imposition on other aggregated indicators such as the consumer price index, the individual welfare, the total tax revenues and CO_2 emissions reduction. The environmental tax induces a general increase in production prices and consequently in the consumption price index (table 1). Environmental tax on *production and distribution of electricity* (case I) produces a relatively higher effect than when it is applied on *Manufacture of gas, distribution of* *gaseous fuels through mains, steam and hot water supply* (case II) and *Manufacturer of other non-metallic mineral* (case III).

The impact of the taxation on social welfare was approximated by estimating the change in individual real income. The aggregated loss of social welfare is often referred as deadweight loss. Measuring the deadweight loss is one of the common approaches to weigh up the economic distortion as a consequence of the new policy. As prices increase, the social welfare is negatively affected in all cases, as shown in table 1. This can be interpreted as a decrease in economic well-being of the society due to the tax imposition. Again the effect of the tax on social welfare is by far higher in case I than in the other two cases. Electricity is an important sector in an economy given that whose outputs are highly demanded not only by the production system but also by the final consumers.

A 6.1% tax rate in the *Production and distribution of electricity* raises a total revenue of 2,467 millions € which is equivalent to a 0.23% GDP share for the year 2007. The total revenues in cases II and III totalise only 25% and 40%, respectively, of revenues generated in case I.

When a 6.1% of environmental tax is applied on the *Production and distribution of electricity*, a 2% reduction of direct CO_2 emission is achieved. The direct effect on emissions can be seen very small; however, a better effect could be indirectly achieved if the revenues raised through the environmental taxation are used for stimulating cleaner energy production by financing innovations in renewable energy technologies.

This would increase the use of renewable energy sources and consequently it would decrease further CO_2 emissions.

Table 1. Economic and environmental variables of the new taxation.

Aggregated indicators	Case I*	Case II**	Case III***
Consumption price change (P_c), %	0.19	0.06	0.07
Private welfare change (ΔW), millions €	-1,348	-318	-140
Total revenue, millions €	2,467	603	914
CO_2 emissions , %	-2.00	-0.63	-0.43

* A tax rate of 6.1% is applied on *Production and distribution of Electricity*; ** A 5.4% tax rate is introduced on *Manufacture of gas, distribution of gaseous fuels through mains, steam and hot water supply;* and *** A 4.3% tax rate on *Manufacture of non-metallic mineral* is applied.

Table 1 shows a clear trade-off between the economic, social and environmental goals when an environmental taxation is levied on the economy. Specifically, the highest improvement in the environment is in case I and it coincides with the worst situation for consumers, despite being when public revenues increase to a greater extend. On the contrary, the best situation in terms of welfare is obtained in case III where CO_2 emissions would be reduced by a small amount. We can also point out that, despite what it is expected under a new taxation on production, the three cases analysed show slight price increases, and this is important if the objectives are focused on avoiding inflation.

These results are very interesting for policy makers, as they allow an analysis of trade-offs in different scenarios. For instance, if the tax is applied on gaseous fuels rather than on electricity, the social impact is 4 times lower meanwhile the CO_2 reduction is only 3 times lower, i.e., better CO_2 emissions reduction can be achieved with lower social effects. Probably the best case is applying the environmental tax on the non-metallic minerals (case III) when almost half of revenues and 25% of CO_2 emissions reduction are obtained with only 10% of social impacts of case I, when the tax is levied on *Production and distribution of electricity*.

To the best of our knowledge there are no similar studies which apply the price model to assess the impact of carbon tax specifically levied on electricity production, manufacturing of gas and other non-metallic minerals of the Spanish sectors. However, similar approaches were used to assess effects of alternative policies in Spain. Labandeira and Labeaga (2002) estimated the energy related CO_2 emissions of sectors in the Spanish economy in the year 1992. Based on the emissions intensity, they defined the hypothetical carbon taxes on fossil fuel consumption and calculated the associated price effects. They considered three different emissions tax rates, namely, the Pigouvian rate[ii], the carbon budget (emissions caps) and the actual damage cost (shadow price). In line with this study, the results of Labandeira and Labeaga (2002) show that sectors such as Coal mining, Electricity, Natural gas, Oil processing, Manufactured gas and Cement are among the most affected sectors which exhibit price increases between 12.1% - 4.1% when a tax rate of 34.8 US$/ton carbon (the rate proposed by the European Commission for the year 1998 as upper estimate) is applied. Llop and Pié (2008) also examined the consequences of a tax levied on intermediate energy uses in the Catalan economy by applying the input-output price model. They simulated the economic impact of three alternative scenarios on energetic activities, namely a 10% tax on energy uses, a 10% reduction in energy uses and finally a combined measure, a 10% tax and a 10% reduction in energy use. A 10% increase in the tax of energy induces relatively high changes in production prices of sectors such as Electrical energy, gas and water; Energy products, minerals, coke, petroleum and fuels; and Other non-metallic mineral products, which exhibit price changes of 4.7%, 3.8% and 1.8%, respectively. As a consequence of the change in production prices, the consumer prises increase, the private welfare is also negatively affected, leading to a reduction in intermediate demand for energy and in pollutant emissions.

Despite the spatial and temporal differences in the related literature, the estimated effects of applying an environmental tax are in line with the results we have obtained in this paper. In all our simulations, the sectors showing high production price changes coincide with the ones in the previous studies. The interesting feature offered by the modelling framework discussed in this paper is the possibility to clearly visualise and analyse trade-offs between economic, environmental and social effects of environmental taxation. Furthermore, rather than discussing new types of environmental taxes, this framework uses the emissions prices established by the EU ETS, scheme already implemented in the EU. The framework presented here is flexible enough to allow simulations with different emissions prices and also to focus on specific sectors within a national economy.

4 Conclusions

In this work we have implemented both an EIO and a Leontief price model to investigate the potential impact of a CO_2 tax in the Spanish economy. We implemented EIO model to identify the three highest emission intensities of sectors that are chosen to apply the environmental tax. The economic impacts of taxation, such as its impacts on production prices, private welfare and public revenues and its effect on the environment through the associated reduction in CO_2 emissions, were analysed from the use of the Leontief price model.

We have considered three illustrative cases. The first one consists of the application of an environmental tax on *electricity production and distribution* sector. The second case is based on a tax on *Manufactures of gas, distribution of gaseous fuels through mains, steam and hot water supply* and, finally, a tax applied on the *Manufacture of other non-metallic mineral.*

The results from the empirical analysis show that there is an unavoidable trade-off among the society, the environment and the economy. For example, a tax on the production and distribution of electricity would to some extent improve the environment by reducing the total CO_2 emissions by 2%, while it would negatively affect the social welfare. Our results suggest that the environmental taxation based on CO_2 emissions could not simultaneously ensure the environmental, economic and social goals. This implies the necessity of looking for complementary and alternative measures to environmental taxation in order to achieve not only environmental advantages but also to ensure economic and social rewards. A further analysis of trade-offs is also important in order to choose the optimum taxation for the best emissions reduction, the highest generated revenues, meanwhile assuring minimum impacts on public welfare.

One of the challenges in putting such policies into action is how to minimise the distortional effects on the economy and society and how to avoid the (possible) trade-off with the environment. This is the most important point that any environmental taxation needs to address in order to enhance the effectiveness of the environmental policy. Therefore, the principal objective that any environmental measure needs to achieve is a win-win strategy for environment, economy and society. The trade-off between the environment and the society could be counter balanced by using the revenue from the tax to compensate those who are negatively affected. Likewise, a better improvement of the environment could also be achieved from the use of part of the revenue in stimulating cleaner production by financing innovations to replace non-renewable energy sources in the energy mix. This also makes an environmental tax a worthwhile policy in climate change mitigation.

The approach discussed here has important policy implications. It can be used in understanding the potential impacts of a certain level of CO_2 price in achieving the emission reduction targets through creating incentives for the use of cleaner technology. The EU ETS, which was launched in 2005, is believed to be one of the largest emissions trading scheme in the world to combat climate change. However, it is seemed to fail in meeting its principal objective as a result of significant CO_2 market price dropped in 2012 to around 5€ per ton from 20€ in 2007. According to our simulation, the potential of the environmental tax would be less than a factor of quarter if the current price is considered to be the tax rate. This may not generate the necessary incentives to most polluting sectors to look for cleaner technologies. However, recently the EU is planning to intervene on the carbon market to increase the price by delaying the number of allowance in the swollen Emissions Trading System. Therefore, studies in the line presented can play a vital role in assessing the effectiveness of current environmental policies (environmental tax or tradable permits) as they highlight how emissions tax on selected sectors could affect not only other sectors but also the economic, social and environmental goals.

Finally, it is worth mentioning some of the limitations and assumptions made in this study. One of the issues we would like to point out is the assumption in which both quantity and price input-output models is based on. In these models the technology is fixed and, therefore, all the effects associated with the environmental tax are short-term impacts. The constraint in relation with the long-term effects could be resolved in the future by developing a non-linear and dynamic IO model. Such model allows the production function to exhibit substitutionbetween intermediate inputs This makes it possible the use of the price model for long-term impact analysis. Generally, the price model limits the analysis to a rough estimation of the potential impact of the tax in the economy. Another extension of the present work will be to apply a Computable General Equilibrium (CGE) model, that allows to capture the link and interdependencies between all the economic agents, what is very important in order to precise the entire effects of the environmental taxation.

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Notes:

[i]Further detail on the environmental tax calculation can be found in Gemechu et al. (2012)

[ii]It is a Pigovian tax rate applied to sectors with the principle of internalizing the negative externalities (damages caused by the emissions). The tax rate is supposed to be equal to the marginal damages.

References

Boratyński J (2002) Indirect taxes and price formation: A model for the Polish economy. Paper presented at the 11th INFORUM World Conference, the Institute of

Economic Forecasting Russian Academy of sciences (IEF RAS), Suzdal, Russia, 8 - 12 September 2003

De Miguel J (2003) Matrices de contabilidad social y modelización de equilibrio general: una aplicación para la economía extremeña. Dissertation, Universidad de Extremadura

European Environmental Agency (EEA) (2009) Greenhouse gas emission trends and projections in Europe 2009: Tracking progress towards Kyoto targets. EEA report, No 9. Available at http://www.eea.europa.eu/publications/eea_report_2009_9. Cited on June 2012

Ekins P (1999) European environmental taxes and charges: recent experience, issues and trends. Ecol Econ 31(1): 39-62

European Commissions (EU) (2002) Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme. Official Journal of the European Communities. L 242

Fullerton D (2001) A Framework to Compare Environmental Policies. South Econ J 68: 224-238

Fullerton D, Leicester A, Smith S (2010) "Environmental Taxes" Dimensions of Tax Design. Ed. Institute for Fiscal Studies (IFS). Oxford University Press. Available at http://works.bepress.com/don_fullerton/37. Cited 21 March 2012

Gago A, Labandeira A, Picos F, Rodríguez M (2006) Environmental taxes in Spain: a missed opportunity. J. Martínez, J.F. Sanz (Eds.), Fiscal tax reform in Spain, Edward Elgar, Northampton

Gemechu ED, Butnar I, Llop M, Castells F (2012) Environmental tax on products and services based on their carbon footprint: A case study of the pulp and paper sector. Energ Policy (in press). DOI 10.1016/j.enpol.2012.07.028

Instituto Nacional de Estadística (INE) (2010a) Atmospheric emissions satellite accounts. 1990 and 1995-2003 series. http://www.ine.es/. Cited 19 January 2011

Instituto Nacional de Estadística (INE) (2010b) Spanish National Accounts, Base 2000. http://www.ine.es/. Cited 5 December 2011

Intergovernmental Panel on Climate Change (IPCC) (2007) Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jaffe AB, Stavins RN (1995) Dynamic Incentives of Environmental Regulation: The Effects of Alternative Policy Instruments on Technology Diffusion. J Environ Econ Manag 29: S43-S63

Labandeira X, Labeaga JM (2002) Estimation and control of Spanish energy-related CO_2 emissions: an input–output approach. Energ Policy 30(7):597–611

Leontief, W., 1946. Wages, profit and prices. Q J Econ 61(1):26–39

Llop M (2008) Economic impact of alternative water policy scenarios in the Spanish production system: An input-output analysis. Ecol Econ 68(1-2):288 – 294

Llop M, Manresa A (2004) Influencia de los precios de los factores y de las importaciones en la economía catalana (1994). Investigaciones Regionales 4:115–129

Llop M, Pié L (2008) Input–output analysis of alternative policies implemented on the energy activities: An application for Catalonia. Energ Policy 36:1642–1648

Manresa A, Polo C, Sancho F (1988) Una evaluación de los efectos del IVA mediante un modelo de producción y gasto de coeficientes fijos. Revista Española de Economía 5:45–64

Matthews HS, Hendrickson CT, Weber CL (2008) The Importance of Carbon Footprint Estimation Boundaries. Environ Sci Technol 42(16):5839-5842

McKean JR, Taylor G (1991) Sensitivity of the Pakistan economy to changes in import prices and profits, taxes or subsidies. Econ Systems Res 3:187–203

Miller RE, Blair PD (2009) Input-Output Analysis: Foundations and Extensions (2nd Ed.). Cambridge University Press, New York

Secretaria de Estado de Energía (SEE) (2007) La Energía de España 2007. Ministerio de Industria, Turismo y Comercio, Gobierno de España

Secretaria de Estado de Energia (SEE) (2010) La Energía de España 2010. Ministerio de Industria, Turismo y Comercio, Gobierno de España

Stern N, Peters S, Bakhshi V, Bowen A, Cameron C, Catovsky S, Crane D, Cruickshank S, Dietz S, Edmonson N, Garbett SL, Hamid L, Hoffman G, Ingram D, Jones B, Patmore N, Radcliffe H, Sathiyarajah R, Stock M, Taylor C, Vernon T, Wanjie H, Zenghelis D (2006) Stern Review: The Economics of Climate Change. HM Treasury, London

Suh, S, Huppes, G (2005) Methods for Life Cycle Inventory of a product. J Clean Prod 13(7):687-697