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General Equilibrium Effects of Policy Measures Applied to Energy: The Case of Catalonia

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1. Introduction

In the last decades, the negative externalities caused by the economic activity on the environment have become a crucial subject in most countries. In particular, it has emerged a debate focused on and the measures that need to be taken to mitigate the adverse effects of human kind on the natural ecosystems. This debate has been intensified during the last twenty years because of climate change (Stern, 2006). Nowadays, there exists the consensus that climate change is a problem that affects the whole world and, accordingly, the solution requires a global response.

On the other hand, researchers have developed a conceptual set to define and implement pollution abatement measures to be successful in preserving the environment and to mitigate the negative effects of humans on the environment. Nowadays, policy makers have at hand different policy measures, which can alternatively be applied in an economy, aimed at reducing the pollution generation. This leads to the question of which are the effects of the different measures, how agents are affected and which are the positive effects on the environment. Then, there is the need of using analytical instruments able to calculate the impacts caused by the alternative policy interventions in order to get the maximum positive effects on environment compatible with the minimum affectation on the economic activity.

Modelling an economy with all its interrelations, agents and sectors is complex. In an economic system, there is a large number of agents, goods and markets, each one characterised by its corresponding optimisation behaviour, that are difficult to be jointly captured in an economic model. For this reason, environmental policies have usually been studied in a partial equilibrium context. However, we must bear in mind that many of the measures have also an impact on variables not directly related with the interventions, because of the indirect effects that have to be added to the immediate (direct) effects. Then, in order to understand the entire impacts of economic policies on the environment or, on the contrary, the effects of environmental protection on macroeconomic variables, we need to use models able to capture the complex interrelations existing between the different sectors and agents of the economy.

The computable general equilibrium (CGE) models are useful instruments to analyse the effects of policy measures and changes in the economic scenarios on the main economic indicators, such as the level of sectoral production, the consumption price index, the GDP, the private income, the public deficit or the level of public activity. Moreover, CGE models can also be used to show the effects on environmental variables such as water consumption, greenhouse emissions and waste generation. One of the main advantages of general equilibrium, compared with partial equilibrium models, is that it allows to capture all the economic agents and their economic optimisation. Given that all the markets and agents are included, the CGE models provide a solution not only taking into account the direct impacts between variables and agents but also taking into account the indirect effects explained by the interdependence between agents and markets.

Recently, computable general equilibrium analysis has become a promising method to assess the impact of different energy and environmental policies on economic and environmental variables. The CGE framework allows to calculate the effects of a certain policy on pollutant emissions, the economic costs associated with this policy, and the economic and social costs and benefits stemming from such public intervention. One of the first studies were Goulder (1992) for the USA, Pireddu and Dufournand (1996) for Italy, and Böhringer and Rutherford (1997) for Germany.

For Spanish applications, Labandeira and Rodríguez (2004) studied the impact of an environmental tax on carbon dioxide emissions. Manresa and Sancho (2005) analysed the costs and benefits of a tax policy aimed at reducing the CO_2 pollution in Spain. Faehn et al. (2009) analysed fiscal and environmental aspects using a general equilibrium model with imperfect competition. At the regional level, André, Cardenete and Velázquez (2005) and González and Dellink (2006) assessed the impact of an environmental tax reform on the regional economies of Andalusia and the Basque Country, respectively.

With regard to the emission objectives, the European Union (EU) signed in 2008 a climate change agreement known as "20-20-20 European Directive". This agreement is aimed at reducing the Union's greenhouse gas emissions by 20% before the year 2020. Additionally, this plan also establishes that 20% of the energy used in Europe has to come from renewable sources, and that energy efficiency has to be improved by 20% in 2020.

Taking into account the recent European directive, it seems crucial to study the different options that policy makers have at hand to reduce the pollutant gas emissions. In this chapter, it is used a CGE model to analyse the economic effects on the regional economy of Catalonia of the implementation of policies applied on the energy activities.[1] Similarly to the present objective, Llop and Pié (2008) analysed the economic impact associated to alternative policies designed to reduce pollutant emissions in the Catalan economy with the use of a linear model of prices based on an input-output framework. This paper analysed the effects caused by a new taxation on the energy consumption and a reduction in the energy used by agents. The present study is a further analysis than that in Llop and Pié (2008) because, as it is based on a general equilibrium model, it reflects not only the structure of production but also the rest of economic agents (consumers, government and foreign sector) in the determination of prices in the economy. The present model also assumes a non-linear technology of production that, differently to the input-output model, allows to show substitution possibilities between the elements that compound the structure of production.

[1] The region of Catalonia is located in the North-East of Spain. It is a very dynamic region representing around 20% of the Spanish GDP and 18% of the Spanish population.

The rest of the chapter is organised as follows. The next section describes the characteristics of computable general equilibrium models and the construction phases which are common in CGE modelling. The third section describes the model for the Catalan economy and the fourth section presents the database used to calibrate all the exogenous parameters. The fifth section shows the main results of the simulations. At the end of the paper, some concluding remarks are pointed out.

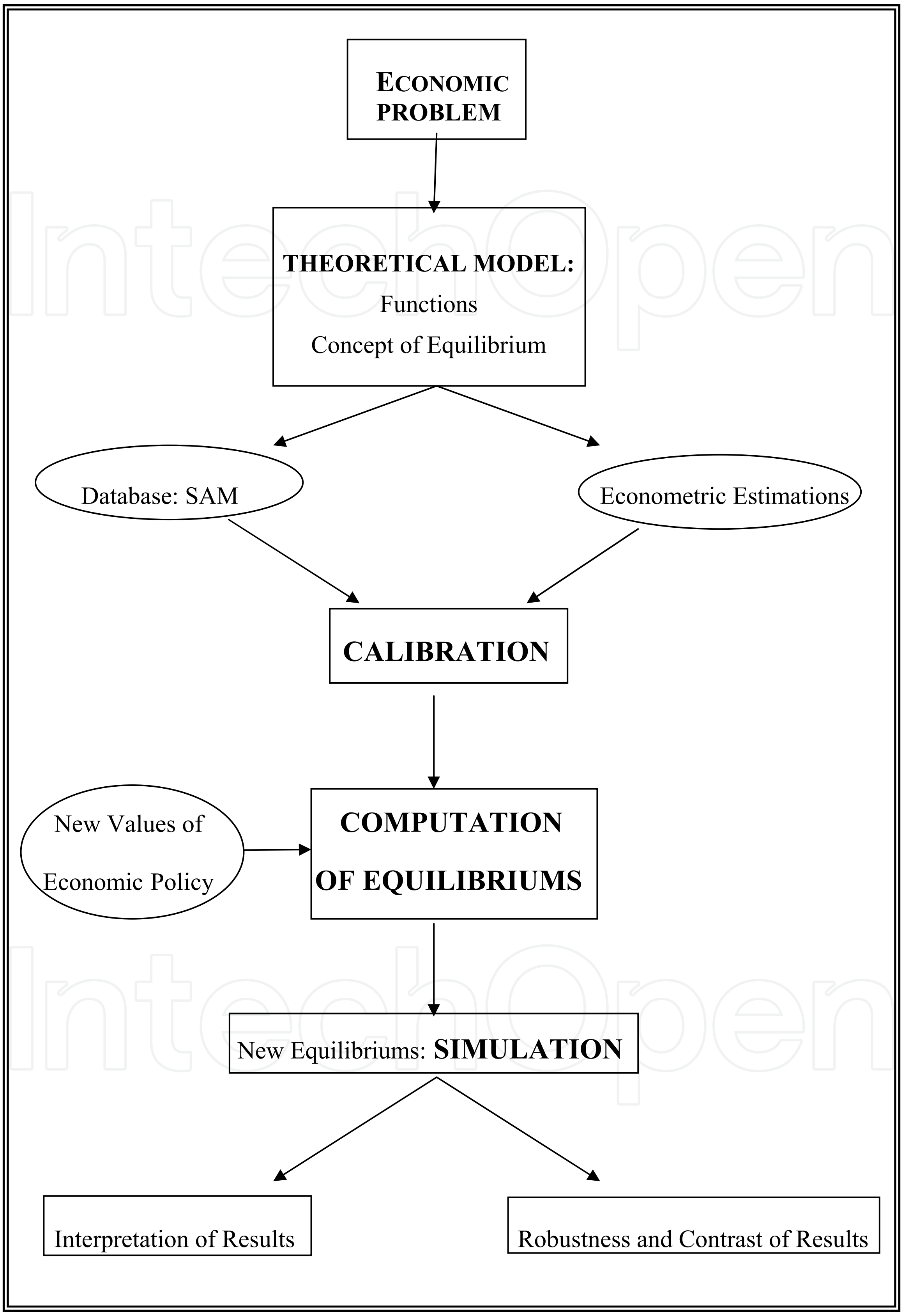
2. Description of computable general equilibrium models

In the last decades, it has been developed a useful set of analytical instruments which have helped economists and policy makers to improve their knowledge about the relationships between economic agents, such as firms, public institutions, consumers and foreign agents. Partial equilibrium models have largely been used to analyse the economic impact of changes in economic scenarios and policy interventions. However, partial equilibrium approaches are focused on the immediate effects existing in a specific economic environment, and do not take into account the indirect effects which, in most cases, can be of importance. Therefore, partial equilibrium approaches do not capture the complete chain of impacts of public interventions and, consequently, the results of partial equilibrium analysis can be inaccurate and incomplete. The consequence is that the outcomes of partial equilibrium studies can lead to imprecise conclusions. Recently, computable general equilibrium models have become useful tools to analyse the effects caused by public interventions and other changes in the economic systems. Generally, general equilibrium approaches make an extensive representation of an economy including all the agents and their decisions of optimisation. Moreover, CGE models make a complete and systematic representation of the way in which agents interrelate among them, and this allows to capture the complete sequence of impacts when there is some alteration in one part of the economic system.

The computable general equilibrium techniques are based on the concept of general equilibrium, which at the same time responds to the Walrasian idea of interrelation and interdependence between agents and markets, to analyse the effects of different economic measures or changes in the economic relations. In fact, a CGE model is an empirical representation of an economy in which all the markets are interrelated and in which the prices of goods, services and primary factors guarantee a situation of equilibrium in this economy.

It is important to bear in mind that under the CGE analysis there is no a unique way of representing an economy, its agents and their optimization behaviour, and this in turn greatly determines the models' final characteristics. From a practical point of view, the structure and characteristics of a particular model will depend, to a greater extent, on both the problem under analysis and the data availability to researchers.

The institutional classification of the economic agents and their optimisation behaviour are crucial aspects in determining the final characteristics of the general equilibrium models. Despite there is a large set of possibilities in designing a CGE model, we can describe some steps that are common within the process of computable equilibrium techniques. Figure 1 schematically reflects the sequence in the construction of an applyed general equilibrium model.



Source: own elaboration.

Fig. 1. Construction of a CGE Model

The construction of a CGE model starts with the definition of a theoretical set that is a simplified representation of the economy under study (Kehoe (1996) and Manresa (1996)). This step is very relevant because, among other decisions, it have to be determined the type of agents in the model and the degree of disaggregation that should be used when representing the economy's agents and institutions and the optimization rules that characterise such agents. As it is logical, the objectives of the analysis will determine the definition of agents and their economic behaviour and, additionally, the availability of information to researchers will force to use a disaggregation according to data.

A second step consists in designing the analytical context in which the economic behaviour of consumers, producers, government and foreign agents is to be identified. Consumers have some initial endowments (of goods and factors of production), and a set of preferences, which allow to obtain the final demand functions for each good. The market demand is the result of adding the individual demands, and it has some important properties; it is continuous, non-negative and accomplishes the Walras' law. As it is well-known, Walras's law says that for any set of prices, the total value of consumers' expenditures equals consumers' revenues. The resulting market demands are homogeneous of grade zero, and this means that only the relative prices are significant in the decisions of consumption and saving of private agents. This is an important property because it means that the changes in the absolute level of prices have no impact on the resulting equilibrium, and only the changes in relative prices modify the agents' decisions.

The production functions of CGE models usually define constant-returns-to-scale, and producers choose those quantities of both primary inputs and factors of production that ensure the maximum level of profits. Despite this is the normal representation of technology, the literature of CGE models can also show increased returns to scale in some sectors and companies as well as imperfect competition (an example of these modifications to the normal model's specification can be found in Bonano (1990)). On the other hand, the equilibrium must guarantee that demand equals to supply in all markets of goods and factors of production. In other words, the equilibrium is characterised by a set of relative prices and levels of production in each industry for which the demand equals to supply in all markets. Despite this is the normal market situation, it can also be defined an excess of supply or surplus in some markets. With constant-returns-to-scale, the objective of maximum profit implies that the only possible solution for sectors is the one that gives null sectoral profits.

CGE models also incorporate the public agent or government, that transfers income to the rest of agents (households and firms), and supplies public goods through the public expenditure activity. As any economic agent, government maximizes its utility, subject to their income restriction. This agent collects taxes, which are the main source of public income, and may have a public deficit which, in this case, is financed by the rest of economic agents.

General equilibrium models also define the external sector, that includes all the income relations of the economy with foreign agents and foreign markets. As there are many different ways to define the external relations of the economy, computable general equilibrium models can differ widely depending not only on the number of foreign agents involved but also on the type of behaviour assumed to this part of the model.

Once the theoretical model and its basic characteristics have been defined, the type of the functional forms of each part of the model has to be decided. The choice of functional forms depends on both the availability of data and the objectives of the analysis. Functions like Cobb-Douglas, Constant Elastic Substitution (CES), Leontief, or Lineal Expenditure Systems (LES) are frequently used because the parameters involved can be easily obtained compared with other analytical expressions that, despite being more general and flexible, have the inconvenient of requiring a large amount of data not always available to researchers.

At this point, when the complete structure of the model and its functional forms have been defined, we need to specify all the values of the parameters (or exogenous variables) involved in the model's structure. These parameters can be obtained by using both econometric estimations and calibration (for instance, Mansur and Whalley (1984) made a complete description of calibration). The method of calibration requires a database that consistently reflects all the flows of goods, services and income between the economic agents during a specific period, which will be considered the reference situation of the economy (benchmark equilibrium). This database is a social accounting matrix (or SAM) which has a structure of a double-entry table containing all the income flows of agents in rows and the corresponding expenditures in columns. Usually, the information required to construct a SAM comes from different sources, such as national product accounts, input-output matrices and other economic surveys (Pyatt (1988)). It is necessary to remark, however, that there are CGE models that do not use any SAM to calibrate their parameters and they use macroeconomic data directly from statistical sources but this is not the normal practice in applied general equilibrium research.

The calibration method has been criticised by econometricians because there is no any statistical test to determine the reliability of the values obtained for the parameters of CGE models (see Hansen and Heckman (1996) for an argument against calibration). Despite these methodological problems, calibration has many advantages given that it requires much less data than economic estimations. This explains why calibration is the most commonly used method in computable general equilibrium research. Related to this subject, Whalley (1991) described the main advantages of using calibration in CGE modelling in contrast with econometric estimations, which can be summarised in the following ideas:

- The large number of parameters of any computable general equilibrium model requires a great number of observations if econometric estimations have to be undertaken.
- There is a difficulty in treating value, and its separation between prices and quantities in observations makes it difficult to estimate the parameters econometrically.
- The large dimension of CGE models implies that the construction of equilibrium datasets (that is, reference equilibrium databases) requires a large set of statistical information; hence the research could not be viable if the construction of time series is needed to econometrically estimate all the parameters involved in CGE models.

Despite the disadvantages of using statistical methods, econometric estimations of parameters can also be used in CGE models (Jorgenson, 1984). Specifically, the literature shows some models that use statistical estimations while other models combine calibration and econometric estimation to obtain all the exogenous variables required.

Once the exogenous parameters have been obtained, the model can be represented as a system of equations where the variables to be determined (i.e. the endogenous variables) are the prices of goods, the prices of services, the prices of factors, the levels of sectoral activity, as well as other relevant variables. At this point, the system can be solved by using a computer program such as MPS/GE, GEMODAL, GEMPACK or GAMS. The computation of the model provides an initial solution, which is considered the starting point of the analysis. This initial solution, or benchmark equilibrium, can be compared with new situations that will be analysed in the model.

The simulation analysis consists of applying new values for the exogenous variables of the model. This procedure, which is in fact an experiment of comparative statics, has the objective of calculating which would be the consequences of adopting economic measures without putting such measures into practice or, in case of being applied, which are the entire economic effects on agents and markets.

The following step in the CGE construction is the analysis and interpretation of the results. In fact, this is a very important phase given that it is crucial to analyze the robustness that must be attributed to the results obtained with the model. Robustness means, on the one hand, whether the variables are sensitive to small variations in some of the parameters of the model, and on the other hand, if the variables are sensitive to certain specifications of the functional forms (see Harrison and Vinod (1992) for a discussion about this problem). This is an important analysis because it allows to identify relevant aspects of the economy that could influence the outcomes of the model.

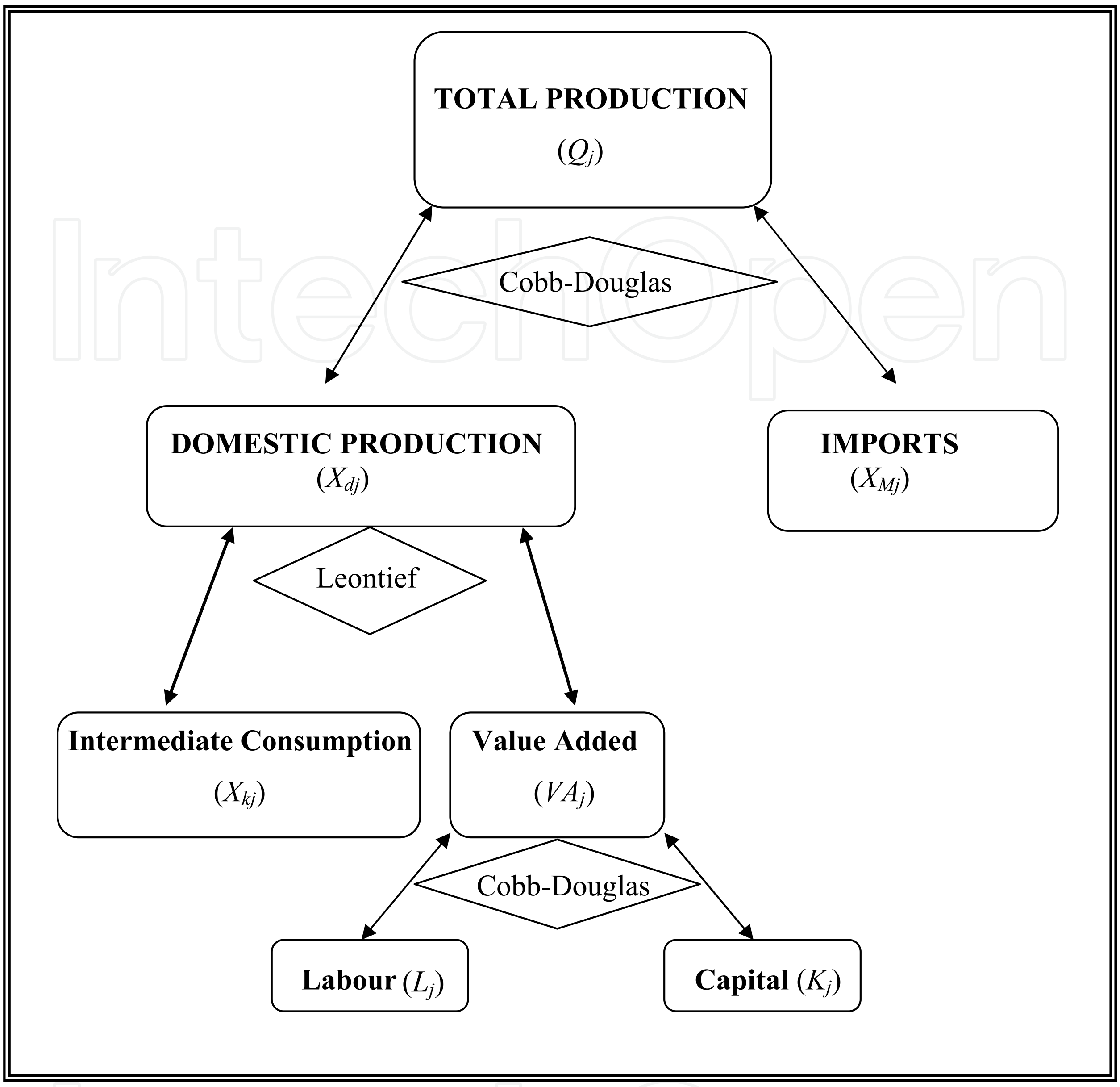
Finally, whenever possible, the results of the model must be contrasted with reality. For instance, Kehoe, Polo and Sancho (1995) contrasted the model used to study the introduction of VAT in Spain (Kehoe, Manresa, Noyola, Polo and Sancho (1988)). In general, the original study was good for predicting industrial prices, levels of production, and prices of factors of production, even though the predictions of the prices of goods were not so good. This last step is not a frequent practice in applied general equilibrium research. The main difficulty in make an ex post evaluation of the models is that usually the measures simulated are never put into practice. However, contrasting the results is very important because it allows us to understand the degree of trust we should attribute to a given model and its results. In this respect, the ex post performance evaluation has to take into account that the model is built from a set of hypothesis that, if not reproduced in the economy, will necessarily invalidate its conclusions.

3. The model

The CGE model for the Catalan economy is a static representation of the regional economy and assumes perfect competition and demand equal to supply in all markets. The model contains fifteen sectors of production, an aggregated consumer, a level of public administration and a consolidated foreign agent, reflecting all the regional relations with abroad. In what follows, I describe the characteristics of the economic agents and the optimization behaviour captured in the model.

3.1 Production

Each sector of production, $j = 1,...,15$, obtains a homogenous good and presents a nested constant-returns-to-scale function. Figure 2 schematically shows the structure of the production function.



Source: own elaboration.

Fig. 2. Nested Structure of the Production Function

The first level of the production function follows the Armington hypothesis (Armington, 1969), in which imports and domestic output are assumed to be partially substitutive. Specifically, the total output in each sector (Q_i) is a Cobb-Douglas aggregator combining domestic production (X_{dj}) and regional imports (X_{Mj}) from abroad:

$$Q_j = \delta_j X_{dj}^{\gamma_j} X_{Mj}^{1-\gamma_j}, \quad 0 < \gamma_j < 1 \qquad j = 1, \ldots, 15, \tag{1}$$

where δ_j is a scale parameter.

The second level of the production function defines the domestic output by using a Leontief aggregator with constant-returns-to-scale:

$$X_{dj} = \min\left[\frac{X_{1j}}{a_{1j}},\cdots,\frac{X_{15j}}{a_{15j}},\frac{VA_j}{v_j}\right], \quad j = 1,...,15 . \tag{2}$$

In this expression, X_{kj} is the amount of k used in the domestic production of j and a_{kj} and v_j are parameters obtained by calibration.

Finally, the third level of the production function calculates the sectoral value added according to a Cobb-Douglas expression:

$$VA_j = \beta_j L_j^{1-\alpha_j} K_j^{\alpha_j}; \qquad 0 < \alpha_j < 1 \qquad j = 1,...,15 , \tag{3}$$

where β_j is a scale parameter and L_j, K_j are the quantities of labour and capital, respectively, used by sector j.

Producers are competitive in both the input and the output markets and their objective consists of minimising production costs, subject to a given level of output. From this optimisation behaviour, I obtain the demand functions of inputs in each sector and, given that I assume constant-returns-to-scale, the corresponding sectoral profits will be zero.

3.2 Consumers

The model reflects an aggregated consumer that has Cobb-Douglas utility function in logarithms, in which consumption and saving (or future consumption) are combined in the following way:

$$U = \sum_{h=1}^{9} \gamma_k \ln c_k + \gamma_s \ln c_s ; \quad \gamma_h, \gamma_s > 0; \quad \sum_{h=1}^{9} \gamma_h + \gamma_s = 1 , \tag{4}$$

where c_h is the consumption of good h and c_s is the private saving. The model distinguishes between production and consumption goods. The consumption goods are obtained by a conversion matrix of fixed coefficients that consequently defines a direct (and linear) relationship between production prices and consumption prices.

The budget restriction of consumers (expression (5)) imposes that the total consumption and saving cannot exceed the household's disposable income. Private income comes from the household's endowments of labour and capital and from transfers, that come from public sector and from abroad. All these revenues are subject to direct taxation on income.

$$\sum_{h=1}^{9} P_h(1+t_h)c_h + P_I c_s \le \left(wL + rK + PTcpi + ETP_F\right)\left(1-\tau\right) . \tag{5}$$

The left side in (5) shows the final consumption: t_h is the effective tax rate on the consumption of h and P_h is the corresponding price. Additionally, the left side of (5) shows private saving that it is valued at the investment price: P_I. The right side in the budget restriction shows the disposable income: wL is the labour income (w is the wage and L is the endowment of labour or total supply), rK is the capital income (K is the endowment of capital and r is the corresponding price), PT_{cpi} shows the public transfers (indexed with the consumption price index: *cpi*), and *ET* are the external transfers from abroad (indexed with the price of external sector P_F). Finally, τ is the effective tax rate on household's income.

The model assumes that the consumer maximises its utility function subject to the budget constraint. From this behaviour, I obtain the demand functions for all the consumption goods and for private saving.

3.3 Government

The government produces public goods and public services that, at the same time, are demanded by himself. The model defines a Leontief utility function for the government, which combines public consumption and public investment in fixed proportions:

$$U^G = \min\left[C_{15}^G, \gamma^G C_I^G\right], \tag{6}$$

where C_{15}^G is the amount of public consumption (in the model, j = 15 is the sector that represents the public services production) and C_I^G is the public investment. The parameter $\gamma^G > 0$ shows a constant proportion between public consumption and public investment.

The government's budget restriction imposes that public consumption and public investment cannot exceed public revenues. These revenues come from the taxation system and must be reduced by the amount of public transfers to households. Specifically, the public budget is defined as:

$$P_{15}C_{15}^G + P_I C_I^G \le I^G + \omega_I^G P_I. \tag{7}$$

In expression (7), ω_I^G is the amount of debt that government can have in the event of deficit and I^G is the income coming from taxation, containing the following taxes:

$$I^G = VAT + DT + PrT + SST - PT_{cpi}, \tag{8}$$

where VAT is the indirect taxation on consumption ($VAT = \sum_{h=1}^{9} P_h t_h c_h$). The direct taxation on private income (DT) is calculated as $DT = (wL + rK + PTcpi + ETP_F)\tau$. Additionally, $PrT = \sum_{j=1}^{15} s_j \left(\frac{P_{dj} X_{dj}}{1+s_j}\right)$ is the taxation on domestic production, with s_j being the tax rate on domestic production. Finally, the social security contributions $SST = \sum_{j=1}^{15} ss_j w L_j^D$, where ss_j is the social security contribution rate in j and $L^D{}_j$ is the sectoral labour demand, complete the tax figures of the model.

3.4 Foreign agent

In the CGE model, the relations of the economy with abroad are represented using an aggregated agent that includes all the regional transactions of income (revenues and expenditures) with the external markets. This foreign agent produces a traded good by using the regional exports as inputs, and following a fixed coefficients technology. Additionally, the economy can both receive transfers from abroad and make transfers abroad at the same time.

The model can reflect a situation of external deficit that must consequently be balanced with the corresponding foreign agent's saving, in order to preserve the macroeconomic equilibrium between total savings and total investment in the regional economy.

3.5 Definition of equilibrium

In the CGE model for the Catalan economy, the definition of equilibrium is based on the Walrasian concept, which it has been extended not only to include producers and consumers, but also government and foreign agents. Specifically, the equilibrium is defined as a vector of prices, a vector of activity levels and a set of macroeconomic indicators that clear all markets and allow all agents to achieve their optimization plans. Mathematically, the model is represented as a set of equations containing the equilibrium conditions in all markets.

With respect to the macroeconomic closure rules used in the model, it have been defined the same for both the government and the foreign sector. These closure rules consist of a variable activity level of government and a fixed public deficit, and a variable activity level of the foreign agent and a fixed trade deficit.

4. Database

The parameters or exogenous variables of the CGE model for the Catalan economy have been calculated by applying the standard calibration procedure. This procedure allows to reproduce an initial equilibrium, or benchmark situation, in which all the prices and activity levels are unitary and the solution of the model coincides with the empirical information shown in the social accounting matrix (or SAM) database. That is, the situation reflected in the data of the regional SAM used is assumed to be an equilibrium situation of the economy.

A SAM is a double-entry square matrix in which each agent is represented simultaneously in a row and a column. This database contains the economic transactions within the production system (as in an input-output table) and, additionally, it also contains all the other transactions of the circular flow (factorial and personal income distribution). Therefore, a SAM completes the typical information of the input-output tables by adding the other relationships of income taking place within the circular flow.

By agreement, the rows of a SAM show the revenues of the economic agents and the columns show the corresponding expenditures. To preserve the accounting equilibrium, the value of income must be equal to the value of expenditure in each agent. This means that the total sum of a row must be equal to the total sum of the corresponding column to preserve the equilibrium between origin and destination of income in all the economic agents.

Table 1 shows the list of accounts included in the regional database, that takes the 2001 as temporal reference. Given the information deficiencies at the regional level, the 2001 SAM for the Catalan economy (SAMCAT) has a simple structure that is described in Llop (2011).

Specifically, the production system is divided into 15 sectors (1 agricultural sector, 9 industrial sectors and 5 service sectors). The SAMCAT also shows nine consumption goods, different than the goods obtained in the production processes. Additionally, the regional

Production Sectors	1. Agriculture 2. Energy 3. Chemistry 4. Metals and electric equipment 5. Automobiles 6. Food production 7. Textiles 8. Paper 9. Other industries 10. Construction 11. Commerce 12. Transports and communications 13. Finance 14. Private services 15. Public services
Consumption Goods	16. Food 17. Tobacco and alcohol 18. Clothes and shoes 19. Housing 20. Furniture 21. Medical assistance 22. Transports and communications 23. Culture and education 24. Other consumption goods
Factors of production	25. Labour 26. Capital
Consumers	27. Consumers
Saving-investment	28. Capital account
Public sector	29. Production taxes 30. Social Security taxes on employers 31. Direct taxes on income 32. Consumption taxes 33. Government
Sector exterior	34. Foreign sector

Table 1. List of accounts in the SAMCAT

database shows two production factors, labour and capital, and a generic account containing the income relations of private consumers. In the SAMCAT, the capital account shows all the sources of saving and investment in the regional economy. The government's accounts involve four different taxes (on production, on personal income, on consumption and, finally, Social Security contributions) and an account that contains the income flows of public administration. Finally, the foreign agent is aggregated into a consolidated account showing imports, exports and income transactions of the regional economy with abroad.

5. Results

The first computation of the model involves the calculation of the reference equilibrium (benchmark situation), in which all the prices and activity levels are unitary and the model exactly reproduces the numerical information contained in the social accounting matrix. Then, the model is used to show the effects of different policies applied to the energy sector that have usually been identified as potentially successful for controlling pollutant emissions.

The simulation analysis consists of making three alternative modifications to the benchmark equilibrium. First, it has been introduced a 10% tax on intermediate energy uses. Second, it has been analysed the effects of a greater efficiency in the energy uses, consisting of a reduction in intermediate energy uses of all sectors of production by 10%. Third, it has also been calculated the joint effects: that is to say, a 10% tax on intermediate energy uses together with a 10% decrease in energy requirements by sectors of production. The simulations undertaken are quantitatively defined for the sake of illustration of the effects involved. Despite the numerical values used can be seen not easily applicable at the reality, the reason why I choose them is simply to clearly show the intensity and the direction of the associated economic impacts.

Before showing the numerical results of the simulations, an additional aspect of the analytical context used should be taken into account. Given that the Walras' law implies that one of the equations in the model is redundant, the wage is considered as numéraire and the price of labour is consequently fixed to one in all the simulations performed. This means that in the new equilibriums the prices are in fact relative prices with respect to the numéraire (the wage).

Table 2 shows the changes in sectoral prices, the changes in the prices of consumption goods and the changes in other prices of the model (price of investment and price of external sector).

The first scenario simulates the effects of a new 10% tax on the energy used in the production system. The new taxation on energy causes a general increase in production prices. Logically, the energy price is the most affected by this policy intervention and its price rise by 11.17%. The effects on chemistry (2.86%), transport and communications (2.47%) and other industries (2.33%) are also significant and show a great reaction of the production prices under the policy simulated. On the contrary, finance and private services are the sectors whose prices are less affected by the taxation on energy (0.47% and 0.77%, respectively).

	Situation 1	Situation 2	Situation 3
SECTORS			
1. Agriculture	1.20%	-0.98%	-0.11%
2. Energy	11.17%	-9.13%	-0.10%
3. Chemistry	2.86%	-2.34%	-0.35%
4. Metals and electric equipment	0.99%	-0.81%	-0.09%
5. Automobiles	1.07%	-0.87%	-0.10%
6. Food production	1.17%	-0.93%	-0.11%
7. Textiles	1.34%	-1.10%	-0.12%
8. Paper	1.32%	-1.09%	-0.12%
9. Other industries	2.33%	-1.90%	-0.21%
10. Construction	1.16%	-0.95%	-0.10%
11. Commerce	1.11%	-0.91%	-0.10%
12. Transports and communications	2.47%	-2.02%	-0.22%
13. Finance	0.47%	-0.38%	-0.04%
14. Private services	0.77%	-0.63%	-0.07%
15. Public services	1.02%	-0.84%	-0.09%
CONSUMPTION GOODS			
16. Food	1.14%	-0.94%	-0.11%
17. Tobacco and alcohol	1.13%	-0.93%	-0.10%
18. Clothes and shoes	1.20%	-0.98%	-0.11%
19. Housing	1.28%	-2.25%	-0.25%
20. Furniture	1.13%	-0.93%	-0.10%
21. Medical assistance	1.09%	-0.89%	-0.10%
22. Transports and communications	1.28%	-2.33%	-0.25%
23. Culture and education	1.13%	-0.93%	-0.10%
24. Other consumption goods	0.90%	-0.73%	-0.08%
OTHER PRICES			
Consumption Price Index (*cpi*)	1.51%	-1.23%	-0.14%
Price of Investment (P_I)	1.10%	-0.90%	-0.01%
Price of External Sector (P_F)	1.80%	-1.40%	-0.02%
Price of Capital (r)	-0.01%	-0.01%	-0.01%
Price of Labour (w)	0.00%	0.00%	0.00%

Situation 1: 10% taxation on intermediate energy uses
Situation 2: 10% reduction in intermediate energy requirements
Situation 3: 10% taxation on energy uses and 10% reduction in intermediate energy requirements

Table 2. Changes in prices (%)

As the consumption goods are a combination of the production goods, the increase in production prices are transmitted to the prices of consumption goods. At the same time, this is reflected in the consumption price index that shows an increase by 1.51%. The inflationary effect of the taxation on energy can also be seen in the investment price and in the price of the external sector (that increase by 1.10% and 1.80%, respectively). The relative price of factors suffers practically no changes, and the price of capital shows an insignificant reduction by 0.01%.

The second modification to the benchmark equilibrium consists of analysing the effects of a 10% reduction in the intermediate uses of energy, that can be driven by greater consumer awareness for more sustainable energy uses or by efforts to increase the efficiency in production processes in terms of the energy requirements. This simulation will give us some idea of how a change (reduction) in energy consumption will affect the main economic variables. From table 2, the reduction in water uses shows a generalised decrease in production prices. Specifically, the prices of energy decrease by 9.13%, the prices of transport and communications decrease by 2.02% and the prices of chemistry decrease by 2.34%. These are the activities most affected by the reduction in energy uses, while the other sectoral prices are less sensitive to the reduction in energy demand.

The prices of consumption also decrease, mainly housing (-2.25%) and transport and communications (-2.33%). The consumption price index, that is compounded by the prices of the consumption goods, shows a significant reduction (1.23%). Finally, table 2 shows that the investment price and the external price also present reductions (being of 0.90% and 1.40%, respectively).

The third simulation examines the effects of a combined policy consisting in a new 10% taxation on the intermediate energy uses and a 10% reduction in sectoral energy uses. A result is that the increased efficiency of energy uses together with a tax on energy has practically no effects on production prices and on consumption prices. Under this situation, the consumption price index shows a small reduction of 0.14%. In fact, this negligible variability in prices suggests that the inflationary effects of the new taxation are practically compensated by the deflationary effects of the decrease in energy requirements. This is an interesting result, mainly if the aim is to avoid inflation of prices.

Table 3 contains the changes in the activity levels of sectors of production and consumption goods in each new situation analysed in the model. As expected, the new tax on energy (situation 1) causes a general decrease in the sectoral activity levels that it is also transmitted to the consumption goods. It is also remarkable that the investment is negatively affected by the decrease in the activity of sectors, and shows a reduction by 1.33%.

The second column in table 3 shows that the decrease in the energy requirements is associated with a positive effect on the activity levels of all sectors with the exception of energy that, once all the interactions in the model have been concluded, reduces its activity level by 7.85%. In the consumption goods, it is interesting to remark the positive effects on the activities of transport and communications and housing that reflect positive effects by 2.36% and 2.28% respectively. The price reductions lead to a greater demand that can be seen in the positive effects on the activity levels of production and consumption. Finally, we can observe that the investment is positively affected by the reduction in energy demand (1.11%).

	Situation 1	Situation 2	Situation 3
SECTORS			
1. Agriculture	-0.39	0.31	0.02
2. Energy	-0.80	-7.85	-9.42
3. Chemistry	-0.02	-0.07	-0.05
4. Metals and electric equipment	-0.27	0.12	-0.08
5. Automobiles	-0.23	0.18	0.01
6. Food production	-0.26	0.21	0.01
7. Textiles	-0.03	0.01	-0.01
8. Paper	-0.07	0.02	-0.02
9. Other industries	-0.24	0.11	-0.07
10. Construction	-1.24	0.65	-0.27
11. Commerce	-0.78	0.62	0.04
12. Transports and communications	-0.75	0.52	-0.04
13. Finance	-0.59	0.41	-0.03
14. Private services	-0.87	0.67	0.02
15. Public services	-0.94	0.78	0.08
CONSUMPTION GOODS			
16. Food	-1.11	0.93	0.10
17. Tobacco and alcohol	-1.10	0.92	0.10
18. Clothes and shoes	-1.13	0.97	0.10
19. Housing	-2.66	2.28	0.24
20. Furniture	-1.10	0.92	0.10
21. Medical assistance	-1.06	0.88	0.10
22. Transports and communications	-2.75	2.36	0.25
23. Culture and education	-1.10	0.92	0.10
24. Other consumption goods	-0.87	0.72	0.08
OTHER ACTIVITY LEVELS			
Investment (Y_I)	-1.33	1.11	0.12
External Sector (Y_F)	0.52	-0.44	-0.05

Situation 1: 10% taxation on intermediate energy uses
Situation 2: 10% reduction in intermediate energy requirements
Situation 3: 10% taxation on energy uses and 10% reduction in intermediate energy requirements

Table 3. Changes in activity levels (%)

The last column of table 3 illustrates the effects of a combined measure of taxation and reduction in the demand for energy. This situation shows a limited modification in the activity levels of the production system with the unique exception of the energy activity, that it has a negative impact of 9.42%. Also the effects on the consumption goods, investment and external sector are very limited.

Table 4 contains some additional aggregated indicators, which allows to complete the understanding of the economic impact of the various scenarios. Specifically, it shows the changes in the real GDP and two measures of the effects on the private agents (changes in the real disposable income of consumers and equivalent variation).

	Situation 1	**Situation 2**	**Situation 3**
Real GDP	-1.18%	0.99%	0.11%
Real Private Disposable Income	-1.46%	1.23%	0.13%
Equivalent Variation (Thousands of Euro)	-1,355.69	1,141.76	122.93

Situation 1: 10% taxation on intermediate energy uses
Situation 2: 10% reduction in intermediate energy requirements
Situation 3: 10% taxation on energy uses and 10% reduction in intermediate energy requirements

Table 4. Changes in other variables (%)

As table 4 shows, the measures cause different impacts on the regional production. The GDP suffers from a reduction in case of applying a new tax on the intermediate uses of energy. On the contrary, the increase in the efficiency of energy uses has a positive effect on the production in real terms. Finally, the combination of a price intervention and a decrease in energy requirements leaves the real GDP practically in the benchmark levels.

The effects on the private agents are also opposite depending on the type of intervention analysed. As the new tax on energy causes an increase in prices, private welfare is negatively affected and both the real private income and the equivalent variation are negative in table 4. On the other hand, the reduction in the demand for energy is associated to a significant improvement in private welfare; the private real income increases by 1.23% and the equivalent variation is around 1,142 thousand of euro. From table 4, it is interesting that the combination of a tax on energy with a reduction in the energy requirements mitigates the negative effects on consumers of the traditional taxation and allows to ensure the benchmark levels of private welfare. This is an important finding and it suggests that price effects should be accompanied with a more sustainable consumption of the energetic goods to avoid the negative impacts of the intervention on households.

The simulation analysis shows that alternative energy policies, which are available to policy makers, cause different effects on the main economic indicators. This is an important finding as it suggests that the economic consequences of environmental measures are not trivial and depend, to a greater extend, on the type of policy implemented.

6. Conclusions

This chapter has defined a computable general equilibrium model, following the walrasian tradition, that has been applied to the Catalan economy with the use of a social accounting matrix for the year 2001. The objective of the analysis has been the study of the economic impact of various policies implemented on the energy sector. The reason why I focus on energy is because the consumption and production of energy is associated with important negative impacts on the environment, as it causes most of the pollutant emissions and, consequently, it negatively affects the process of climate change.

The results show that a tax on intermediate energy uses increases the regional prices (production prices, consumption prices, consumer price index, investment price and external price) and this has a clear negative effect on private welfare (real disposable income and equivalent variation) and on regional production (real GDP). On the other hand, when energy uses are reduced, the regional prices decrease and this causes a positive effect on private welfare and on regional GDP. When a tax is combined with a reduction in the intermediate demand for energy, production prices and the consumer price index are very close to zero. Additionally, the effects on GDP and private welfare are slightly positive.

Policy makers have a set of measures to be applied that can help to accomplish environmental goals. The analytical method presented in this chapter provides interesting insights about the economic consequences of policy interventions aimed at reducing the negative impacts on the environment. The results in this paper show that different policies can have different effects on production prices, consumer price indices, GDP and private welfare.

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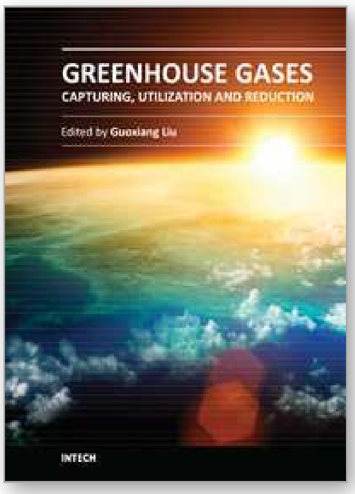

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