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**"Economic impact of alternative policy measures implemented on the energy activities of the Catalan production system: an input-output analysis"**

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**DEPARTAMENT D'ECONOMIA**
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# Economic impact of alternative policy measures implemented on the energy activities of the Catalan production system: an input-output analysis*

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*Laia Pié*[2]

*The aim of the paper is to analyse the economic impact of alternative policies implemented on the energy activities of the Catalan production system. Specifically, we analyse the effects of a tax on intermediate energy uses, a reduction in the final production of energy, and a reduction in intermediate energy uses. The methodology involves two versions of the input-output price model: a competitive price formulation and a mark-up price formulation. The input-output price framework will make it possible to evaluate how the alternative measures modify production prices, consumption prices, private welfare, and intermediate energy uses. The empirical application is for the Catalan economy and uses economic data for the year 2001.*

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## 1. INTRODUCTION

In recent years, the increase in the economic activity of modern societies has led to an increase in the standard of living and welfare. This economic development is linked to growing pressure on the environment, mainly the result of the exploitation and use of energy and natural resources, but also of an increase in population, motor vehicle transportation, and new techniques for making agriculture more productive or industry more efficient. We should bear in mind that the environment is the source of all the materials that people use to satisfy their needs, and it is also the final destination of the pollutants generated. Consequently, environmental policies must consider not only the negative effects of economic activities, but also the use and preservation of natural resources.

One of the major problems of resource analysis is the relative lack of energy products and the fact that some of them are not renewable (for example, petroleum, natural gas and coal). The use of energy in production and consumption activities is growing, and this often leads to inadequate consumption of these energy products. This, connected with a lack of energy saving and energy efficiency, produces a continuous increase in the demand for energy resources. In this paper, we analyse the effects of alternative policies which may help to ensure that energy products are better used and that sustainable development combined with economic growth can be achieved.

In recent decades, the input-output price model has become a useful instrument for analysing production relations. For example, Manresa, Polo and Sancho (1988) used an input-output price model to evaluate the new indirect taxes established after Spain had joined the EEC. McKean and Taylor (1991) built an input-output price model for the

Pakistan economy to measure how alterations in the prices of imports and sectorial inputs affected internal costs of production. Llop (2006), on the other hand, used a price model to analyze the economic impacts of alternative water policies on the Spanish production system. In one of the applications of the input-output price model for Spanish regions, Cardenete and Sancho (2002), analysed the weights and the elasticities of the indirect taxes in the Andalusian economy, in order to establish how they affected the competitiveness of the regional production structure. De Miguel (2003) used the input-output price model to analyze price changes in Extremadura caused by alterations in the structures of sectorial prices and indirect taxation. More recently, Llop and Manresa (2004) used an input-output price model to evaluate the influence of factor and import prices on regional prices in Catalonia.

In the literature there is not a single study that uses the input-output price model to analyse the energy activities. There are several, however, that use the quantity-oriented input-output methodology. Particularly interesting among these is the study by Hudson and Jorgenson (1974), who proposed a methodology that joined an input-output model with an econometric model to evaluate the impact of policy measures on the supply and demand for energy. Forsund (1985) used an extension of the input-output model to analyze air pollution. Later in the eighties, Proops (1988) used the extended input-output model to devise indicators on direct and indirect consumption of energy. In the nineties, Proops, Faber and Wagenhals (1993) compared Germany and the United Kingdom, taking the indicators that Proops himself proposed in 1988, and applying them to air pollution. Hawdon and Pearson (1995) applied an input-output model to ten production sectors in the United Kingdom to show how the interrelations among energy, environment and economy can be analysed.

For Spanish applications, Pajuelo (1980) used an extended input-output quantity model to study air pollution. Other important contributions have been made by Alcántara and Roca (1995) and Antón et al. (1996). The former developed an input-output methodology for measuring the demand for energy and carbon dioxide emissions. The latter used the input-output table for the Spanish economy to evaluate the level of $CO_2$ emissions in several growth scenarios of the domestic economy. Morillas, Melchor and Castro (1996) made a dynamic study of the influence of demand structure on economic growth and air pollution in Andalusia. More recently, Manresa and Sancho (2004) estimated sectorial energy intensities and $CO_2$ emissions for the Catalan economy. In order to evaluate the energy intensities, they used the SAM (Social Accounting Matrix) multiplier analysis.

The purpose of this article is to use an input-output price model to analyze the economic impact of different policies implemented on the energy activities of the Catalan production system. We focus on energy sectors because the use of energy and the production of energy goods exert a negative pressure on the environment. The emissions caused by energy activities are very important in most economies and this explains why this activity has received the attention of public authorities when they define environmental measures of pollution control.[3]

In this paper we evaluate how the Catalan production sectors react under new policy scenarios, which modify the regulations and taxes on energy. Particularly, we use two versions of the input-output model: a competitive price formulation and a mark-up price

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3. Information on energy emissions in Catalonia is not available. In Spain, for example, in the year 2000 energy activities were responsible for 74% of the sulphur oxide emissions, 24% of the nitrogen oxide emissions and 34% of the carbon dioxide emissions.

formulation. These two versions behave unevenly, since they differ in their hypotheses about how production prices are established. The competitive formulation can be interpreted as a short-term setting in which production prices are equal to the average cost of production. The mark-up formulation can be interpreted as a long-term setting in which production prices lead to a fixed capital rent.

The results of our simulations show that a tax on intermediate energy uses increases prices and reduces the intermediate demand for energy. A reduction in energy production, however, increases prices, further reduces the demand for intermediate uses, and has worse welfare effects. Another simulation reduced intermediate energy uses, which reduces prices and energy uses and, unlike the other situations, has a positive effect on welfare. We also calculated the joint situations of a tax on energy uses together with a decrease in energy uses. In this case, production prices and the consumer price index are very close to zero, there is a sharp decrease in the intermediate demand for energy and private welfare is positive. That is, the combination of a tax on energy uses and an improvement in the efficiency of the energy requirements of the production system seems to attain both the environmental and economic objectives: energy consumption is reduced, prices do not increase and private welfare is preserved. Finally, we reduced energy production and applied a tax on energy uses. In this situation, energy consumption increases considerably and the consumer price index increases more than in the other situations.

This paper helps to explain the economic impact of a variety of policies implemented on energy activities within the Catalan production system. This information helps us to understand the relation between the economy and the environment, and can be useful for implementing resource policies that guarantee sustainable development and economic efficiency.

The article is structured as follows. In the second section we present the two versions of the input-output price model: the competitive formulation and the mark-up formulation. In section 3 we describe the results of the simulations for Catalonia. Finally, the article ends with some concluding remarks.

## 2. THE PRICE MODEL

The analytical framework used to evaluate the economic impact of the policies implemented on energy activities is based on the Leontief price model. This approach assumes that the units of production are the industries, each one of which produces a single good by means of the combination of several goods (intermediate inputs) and primary factors (labour and capital) in fixed proportions, under the assumption of constant returns to scale. This technology, in which the outputs produced and the factors are used as inputs, assumes that sectorial benefits are equal to zero. On the other hand, it should be pointed out that the model ignores the consumer's utility function so the final demand does not take part in the price definition.

We use two versions of the input-output model: a competitive price formulation and a mark-up price formulation. The first version assumes that the sectorial prices are equal to the average cost of production. Therefore, if we bear in mind that $j$ = 1, 2…., 27, the price structure for the branch of activity $j$ can be expressed as:

$$p_j = (1+\tau_j)\left[\sum_{i=1}^{27} p_i a_{ij} + (1+s_j)\,wl_j + rk_j + (1+t_j^m)\,p_j^m m_j\right]. \qquad (1)$$

In this equation, $p_j$ represents the price of production in sector $j$; $w$, $r$ and $p_j^m$ are, respectively, the price of labour (wage), the price of capital and the price of imports. Additionally, $a_{ij}$ stands for the input-output coefficients; $l_j$, $k_j$ and $m_j$ are coefficients that represent, respectively, the labour, capital and imported goods in $j$. Finally, $s_j$ is the tax rate of the Social Security paid by sector $j$, $t_j^m$ represents the ad-valorem rate of the imports in $j$, and $\tau_j$ is the ad-valorem tax on the production in net terms.

The simulations include a tax on the energy used by the sectors. Once we have added this tax, we can use the following expression to evaluate the effects on prices:

$$p_j = (1+\tau_j)\left[\sum_{i \neq E}^{27} p_i a_{ij} + (1+t_E)\, p_E\, a_{Ej} + (1+s_j)\, wl_j + rk_j + (1+t_j^m)\, p_j^m m_j\right], \qquad (2)$$

where $E$ = 3, 4 represent the energy sectors, and $t_E$ is a tax on intermediate energy uses.

The second version of the input-output model is a mark-up price formulation, which defines the prices of production as:

$$p_j = (1+T_j)(1+\tau_j)\left[\sum_{i=1}^{27} p_i a_{ij} + (1+s_j)\, wl_j + rk_j + (1+t_j^m)\, p_j^m m_j\right], \qquad (3)$$

where $T_j$ is the benefit tax or mark-up in sector $j$. When we add a tax on the energy sectors, expression (3) is modified as follows:

$$p_j = (1+T_j)(1+\tau_j)\left[\sum_{i \neq E}^{27} p_i a_{ij} + (1+t_E)\, p_E\, a_E + (1+s_j)\, wl_j + rk_j + (1+t_j^m)\, p_j^m m_j\right]. \qquad (4)$$

The two versions of the input-output model differ in the way they treat the sectorial benefits. For the competitive price approach, we assume that $r$ is constant and this involves a fixed benefit in all the productive activities ($rk_j$). This approach can be interpreted as a short-term scenario, in which the capital price and benefits are constant. Therefore, this version of the model will show the immediate effects that the new policies have on production prices. The second version of the model assumes that the production sectors have a constant rate of profit ($T_j$), which in turn means that there must be a fixed rate of capital returns in all branches of production. This situation can be interpreted as a long-term scenario, in which production prices maintain a fixed percentage of sectorial benefits.

The results of the empirical analysis will reflect the variations of prices in levels and percentages, since the calibration procedure assumes that all the reference prices are equal to unity. Thus, the results will be a measure of the price indices ($p_1, p_2, ..., p_{27}$), which have been considered endogenous in the model definition.

Apart from analyzing the effects on production prices, we can also evaluate how the different policies implemented on the energy activities affect the consumption prices. Namely, the consumption prices ($p_c$) are defined endogenously using a normalized basket of goods, which define the weights of the final prices:

$$p_c = \sum_{j=1}^{27} p_j \alpha_j \, , \tag{5}$$

where $p_j$ are the prices of production, and $\alpha_j$ represents the share of final consumption for each good $j$ with respect to all the goods consumed: $\alpha_j = \frac{C_j}{C}$.

It is also possible to analyze the effects on intermediate energy uses. If we assume that in each $j$ = 1, 2, ..., 27, the intermediate costs of energy are kept constant, it follows that:

$$p_E x_{Ej} = p'_E \, x'_{Ej} \; ,$$

where $p_E$ ($E$ = 3, 4) are the prices of the energy in the benchmark equilibrium and $p'_E$ are the prices in the simulations. Similarly, $x_{Ej}$ is the intermediate demand for energy in the benchmark equilibrium, and $x'_{Ej}$ the demand in the simulations. If we consider that all the benchmark prices are equal to unity -that is to say $p_E$ = 1- the new uses of energy in sector $j$ are calculated as:

$$x'_{Ej} = \frac{x_{Ej}}{p'_E}.$$

Finally, the amount of energy used in the production system ($X'_E$) with the new settings is equal to:

$$X'_{Ej} = \sum_{j=1}^{27} x'_{Ej} = \sum_{j=1}^{27} \frac{x_{Ej}}{p'_E}. \qquad (6)$$

We can also obtain an approximation of the influence that each setting exerts on the consumers' welfare. In particular, the changes in private welfare ( $\Delta W$ ) are calculated using the following expression:

$$\Delta W = W - W' = \sum_{j=1}^{27} p_j C_j - \sum_{j=1}^{27} p'_j C_j = \sum_{j=1}^{27} \left(p_j - p'_j\right) C_j, \tag{7}$$

where $p'_j$ is the consumption price of good $j$ after the simulations, $p_j$ is the consumption price of $j$ before the simulations, and $C_j$ is the consumption of $j$. A positive difference represents a better situation in terms of consumer welfare, and a negative difference represents a worse situation. This comparison gives us an estimation of the variations in real income of the consumers after the different simulations.

When a tax on intermediate energy uses is introduced, the public revenues ($R$) are calculated as:

$$R = \sum_{j=1}^{27} t_E \, p'_E \, x'_{Ej}. \tag{8}$$

The method of analysis described above allows us to evaluate the effects on production prices, consumption prices, intermediate energy uses, and private welfare under the different policies that affect the energy sectors. All this information is a considerable help in defining and implementing measures for improving the industrial efficiency of energy consumption.

## 3. EMPIRICAL RESULTS

In our empirical application we used data extracted from the latest input-output table available for Catalonia, for the year 2001 (IDESCAT, 2007). The input-output table makes it possible to construct a matrix representation for the uses and resources of the productive sectors of the Catalan production system, which are expressed in basic prices.

The input-output table used shows a sectorial disaggregation of twenty-seven production sectors: two agricultural sectors, two energy sectors, twelve industrial sectors, a branch of the building industry and, finally, ten branches of the service sectors.

The results provided by the Leontief model are the final effects of an exogenous modification in the cost items, once all the reactions and interactions in the production process have been completed. In particular, an increase in the expenditures of the production sectors are associated to an increase in production prices, which makes it possible to retrieve these additional expenditures, and to keep a sectorial benefit equal to zero in the modified setting.

The simulations carried out not only introduce a 10% tax on intermediate energy uses[4] but also a 10% reduction in the energy production for purposes of comparison. Another simulation analyses greater efficiency of energy uses, consisting of a reduction in intermediate energy uses by 10%. We have also calculated joint effects: that is to say a 10% tax on energy uses together with a 10% decrease in energy uses, and a 10% reduction in energy production together with a 10% tax on energy uses.

The input-output price model provides an interesting view of how the various policies analysed affect prices and energy markets. The results also show the impacts on the amount of intermediate demand for energy. This provides information which can be used to

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4. According to Manresa and Sancho (2004), we should consider which mechanisms, or public policies, would induce economic agents to introduce new technologies entailing huge energy savings and the subsequent reduction in the emissions of pollutants. The result of such consideration by economists (see Bovenberg & Cnossen (1995)), the public authorities of many countries, and environmental conferences such as the ones held in Toronto (1988) Cairo (1990), Rio (1992) and Berlin (1995) has been the introduction of environmental taxes as an instrument of control and a fundamental source of funds to regulate the various sources of energy sources and their emissions.

define and implement resources policies in order to guarantee the proper use and consumption of energy.

Table 1 shows the changes in production prices after the various simulations. The rows show the production activities, whereas the columns show the prices in the competitive formulation and the mark-up formulation.

[PLACE TABLE 1 HERE]

The first two columns show how production prices adapt when we introduce a 10% tax on intermediate energy uses. This tax causes a general increase in production prices. In particular, the price of energy sector 3 rises by 3.834% in the competitive formulation and by 3.859% in the mark-up formulation. If we look at sector 4, we observe higher price effects (4.726% in the competitive formulation and 5.727% in the mark-up formulation). On the other hand, a closer look at the first two columns reveals that production prices rise in all other sectors, but the chemical industry (sector 9), other non-metallic mineral products (sector 11) and transport and network communications (sector 20) are particularly sensitive to taxation on energy uses. It is remarkable that the two versions of the model differ in the impacts on production prices, and that long-term prices are higher than short-term ones.

The second simulation (situation 2) consists of a reduction in the energy production by 10%. When this simulation is applied, there is a general increase in production prices. Namely, if we focus on the energy sectors, the price of sector 3 rises by 15.865% in the competitive formulation and by 15.896% in the mark-up formulation, and the price of sector 4 rises by 16.971% in the competitive formulation and by 18.215% in the mark-up formulation. Additionally, there is a general increase in the other production prices. The chemical industry (sector 9), other non-metallic mineral products (sector 11) and transport and network communications (sector 20) are most affected by the reduction in energy production. Note that, in this simulation, prices are much higher than in the previous one in which a tax was imposed on energy uses, and that prices in the competitive model are lower than those in the mark-up model.

In situation 3 we reduce the sectorial uses of energy by 10%, and this causes a general decrease in production prices. In sector 3 there is a price decrease of 3.560% and 3.581% in the competitive and the mark-up formulation, respectively. In sector 4, prices drop by 4.372% in the competitive formulation and by 5.280% in the mark-up formulation. Again, the results show a wide range of sectorial variation, and prices in the chemical industry (sector 9), other non-metallic mineral products (sector 11), and transport and network communications (sector 20) are most affected by the reduction in the uses of energy. Finally, as in the previous situations, long-term prices react with more intensity than short-term prices.

Situation 4 shows the effects of a 10% reduction in energy uses combined with a 10% tax on energy uses. One interesting result is that, with the exception of energy production (sector 3 and sector 4), changes in production prices are very close to zero.[5] Moreover, prices in the other sectors are close to zero as well. This suggests that it may be possible to put into practice an energy policy that intervenes in energy prices and quantities simultaneously, and barely modifies production prices.

5. The price in sector 3 decreases by 0.368% in the competitive formulation and by 0.370% in the mark-up formulation, while the price in sector 4 decreases by 0.452% in the competitive formulation and by 0.548% in the mark-up formulation.

The last two columns in Table 1 show the effects of a reduction in energy production by 10% combined with a 10% tax on the uses of energy: that is, we apply situations 1 and 2 together. In this simulation, there is a generalized increase in prices, with the chemical industry (sector 9), other non-metallic mineral products (sector 11) and transport and network communications (sector 20) being the non energy sectors that most increase their prices. The energy prices also go up; in sector 3, the price rises by 21.044% in the competitive formulation and by 21.115% in the mark-up formulation, whereas in sector 4 the price rises by 23.383% and 26.016%, respectively.

The conclusion we can draw from Table 1 is that the energy policies analyzed have very different consequences on production prices. Measures applied to the supply side of the energy market tend to increase prices, and measures applied to the demand side tend to decrease them. The combination of a tax on energy uses and a reduction in demand (situation 4) suggests that it is possible to generate practically no effects on production prices. These empirical results show that it is possible to put into practice energy measures that have nearly null impacts on production prices. This is very valuable when the objective is to avoid inflation.

We can complete the analysis by calculating some additional aggregated indicators, which will give us a better understanding of the economic impact of the various scenarios. Table 2 shows the changes in the consumer price index, the intermediate demand for energy, the public revenues of the taxation on intermediate energy uses and, finally, private welfare.

[PLACE TABLE 2 HERE]

The consumer price index has been calculated by weighting the changes in the sectorial prices reported by the model according to the relative significance of the sectorial consumption in relation to total consumption in the year 2001. We extracted the information on sectorial consumption from the input-output table for Catalonia for the year 2001. The taxation on intermediate energy uses increases the consumer price index, which is higher in the mark-up formulation than in the competitive formulation (0.746% and 0.510%, respectively). On the other hand, the 10% reduction in energy production increases the consumer price index by 0.922% in the competitive model and by 1.188% in the mark-up model. In contrast, the demand-side policy of reducing energy uses by 10% decreases the consumer price index by 0.470% in the competitive model, and by 0.683% in the mark-up model. On the other hand, if we combine the demand-side policy with the tax on the energy uses, the effects on consumption prices are practically insignificant (-0.049% in the competitive formulation and -0.071% in the mark-up formulation). This suggests that it is possible to implement energy policies that have barely any effect on the final prices of the economy. However, if we combine the supply-side policy with the tax on energy consumption, the consumer price index increases (1.565% in the competitive formulation and 2.131% in the mark-up formulation). This simulation, therefore, leads to the highest consumer price index of all the simulations analysed.

Table 2 also shows the changes in the amount of energy used within the production sphere. If we apply a 10% tax on the energy, there is a 12.820% reduction in the sectorial demand for energy in the competitive version of the model, and a 13.242% reduction in the mark-up version. In situation 2, when energy production is reduced, there is a much higher decrease in the energy consumption than in the previous situation (-17.452% in the competitive definition, and -17.904% in the mark-up definition). If we analyze the demand-side policy, we again observe a reduction in energy uses (-6.281% for the competitive definition and -5.820% for the mark-up definition). If we combine the demand-side policy with the tax on energy uses, there is a greater decrease in energy uses and, in addition, the effect is almost equal in the two versions (-17.845% in the competitive and -17.805% in the mark-up). Finally, when a tax is combined with a reduction in energy production, there is a 28.517% decrease in energy uses in the competitive model, and 29.295% in the mark-up model.

The public revenues raised by the tax implemented on energy uses appear in table 2. In the first situation, when a 10% tax on intermediate energy uses is introduced, the revenues total 1,068,355 million euros in the short term and 1,072,083 million euros in the long-term. When a demand-side policy is combined with a tax (situation 4) the revenues raised by the two versions of the model are very similar (1,041,972 million euros in the competitive model and 1,041,619 million euros in the mark-up model). Finally, a supply-side policy combined with a tax (situation 5) generates 1,158,645 million euros of public revenue in the competitive model, and 1,168,060 in the mark-up model. To conclude, public revenues are independent of the simulation and the version of the model analysed, since the values in table 2 are very similar.

The effects on private welfare are measured in millions of euros. Depending on the version of the model and the political setting, the results are very different. If we apply a tax on intermediate energy uses, private welfare suffers a negative effect of 460,479 million euros in the competitive model, and 673,536 million euros in the mark-up model. Note that the effect on consumers is especially significant in the mark-up formulation, as it reduces private welfare by 46% more than in the competitive model. When energy production decreases, private welfare drops by 832,182 million euros in the competitive model and by

1,072,357 million euros in the mark-up model. The difference between these two values is approximately 29%. On the other hand, a reduction in energy uses has a positive effect on private welfare of 424,721 and 616,470 million euros depending on the version of the model. The combination of a reduction in energy uses with a tax (situation 4) improves private welfare (44,014 million in the competitive definition and 64,105 million in the mark-up definition). And finally, when production is reduced and a tax applied on energy uses, private welfare decreases considerably (1,923,376 million euros and 1,412,557 million euros, respectively). Therefore, the impacts on consumer welfare are very sensitive to the way in which the production system defines production prices.

Taxation on intermediate energy uses (situation 1) increases production prices and the consumer price index. These effects lead to a decrease in the intermediate demand for energy and, as energy consumption is one of the main sources of atmospheric pollution, this measure would ensure the environmental objectives. However, from the consumer's point of view, the consumer price index rises and this has a negative effect on welfare.

When energy production is reduced, both production prices and the consumer price index rise. There is also a reduction in intermediate energy uses, and a negative effect on private welfare. Again, this policy seems to be positive for the environment, but is worse for consumers, because it has a negative effect on welfare.

When energy uses are reduced, both production prices and the consumer price index fall. There is a reduction in intermediate energy uses, and a positive effect on welfare. Therefore, this is a good policy for consumers, since prices go down, but not so good for the environment, as the reduction in the intermediate demand for energy is quite small.

When a tax on intermediate energy uses is combined with a reduction in the intermediate demand for energy (situation 4), both production prices and the consumer price index are very close to zero. There is a sharp decrease in the intermediate demand for energy, and there is a positive effect on consumer welfare. That is, this is a good policy for the environment, since it considerably reduces energy consumption, and is positive for private welfare. In conclusion, the combination of a tax on energy uses and an improvement in the energy efficiency of the production system seems to be a measure that accomplishes both economic and environmental goals. Specifically, this situation suggests that it is possible to avoid inflation, collect public funds, preserve private welfare, and reduce energy consumption within the production sphere.

Finally, a tax on the intermediate demand for energy in combination with a reduction in energy production increases production prices and the consumer price index. Intermediate energy uses fall considerably, whereas consumer welfare is negatively affected. This would be a successful policy for the environment because, of all the policies analyzed, it is the one that most reduces intermediate energy uses. On the other hand, it is not so good for consumers, who find their welfare considerably reduced.

This analysis shows that policy makers have a set of measures that can help to reduce energy consumption. This illustrates the importance of improving our knowledge of the consequences of alternative policies implemented in the energy sectors. In order to understand the effects involved, we need to capture the complex relationships that exist within the economy, and we also need to take into account the different channels through which the impacts are transmitted. Our results suggest that the policies analysed have different effects on production prices, consumer price indices, tax collection, intermediate demand for energy, and private welfare.

Nowadays, public authorities try to adopt policies that reduce atmospheric pollution. The analytical context described in this paper can help to define and apply political interventions that reduce both intermediate energy uses and the atmospheric pollutants that may have negative effects on the environment.

## 4. CONCLUSIONS

In this article we have defined a price model, based on the traditional input-output model, and applied it to the Catalan production system for the year 2001. Our purpose was to analyze the economic impact of various policies implemented on the energetic activities. Energy is a basic resource for social and economic welfare, since it gives people mobility and comfort and it is essential for the production of most industrial activities. Moreover, the use and production of energy exerts considerable pressure on the environment, by influencing climate change, damaging natural ecosystems, impoverishing the environmental profile and harming human health.

We have used two versions of the input-output model: a competitive version and a mark-up version. The competitive version can be regarded as a short-term scenario in which production prices are equal to the average cost of production. In contrast, the mark-up version is a long-term scenario, in which production prices entail fixed capital returns.

The two formulations of the input-output model have been used to simulate five energy policy scenarios. The first one involves a 10% tax on intermediate energy uses. The second one reduces energy production by 10%, and the third one reduces intermediate energy uses by 10%. Later, we analyze the effect of applying situation one and three together: that is, a reduction in energy uses by 10% and a 10% tax on intermediate energy uses. Finally, we combine situation one and two, by reducing the production of energy by 10% and applying a 10% tax on energy uses.

The results show that a tax on intermediate energy uses increases the consumer price index, and this decreases the intermediate demand for energy and has a negative effect on private welfare. Similarly, when the production of energy is reduced, the consumer price index goes up and the intermediate demand for energy goes down, which has a negative effect on welfare. On the other hand, when energy uses are reduced, both the consumer price index and intermediate energy uses decrease, and there is a positive effect on welfare. 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. There is a sharp decrease in the intermediate demand for energy and a positive effect on consumer welfare. Finally, when we apply a tax and a reduction in energy production, energy consumption reduces considerably, the consumer price index increases more than in other situations, and there is a negative effect on private welfare.

The comparison of the two versions of the model shows that prices and private welfare are very sensitive to the price in the production sphere, whereas the demand for energy is quite similar in the two versions of the model. This could mean that the impacts on the uses of energy resources do not depend on how the production system sets production prices

The analytical approach used in this paper gives interesting results that can help to design and implement policies that help to reduce the intermediate consumption of energy, and so decrease the amount of atmospheric pollution that may be caused by an inappropriate use of energy. In this sense, the input-output price model is a useful method that shows the effects that new political actions have on production activities because it captures the complex relations within the production system.

We would like to stress that the conclusions we draw from the model should be interpreted cautiously, because of the restrictions of the Leontief analysis. These limitations come from the lack of substitution between factors and the null role of final demand in the economy price setting. Despite these deficiencies, the model also has unquestionable advantages. The faithful link with economic activity shows the effects of interdependence between production sectors. The Leontief model also makes it possible to perform a disaggregated analysis of production activities, and this leads to greater knowledge of the reality of the production sphere.

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**Table 1: Changes in production prices (%)**

| Sectors | Situation 1 | | Situation 2 | | Situation 3 | | Situation 4 | | Situation 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Competitive | Mark-up | Competitive | Mark-up | Competitive | Mark-up | Competitive | Mark-up | Competitive | Mark-up |
| **1. Agriculture** | 0.257% | 0.393% | 0.287% | 0.439% | -0.237% | -0.360% | -0.025% | -0.038% | 0.602% | 0.926% |
| **2. Fishing** | 0.329% | 0.375% | 0.367% | 0.418% | -0.305% | -0.347% | -0.032% | -0.036% | 0.766% | 0.875% |
| **3. Energy products, minerals; coke, petroleum and fuels** | 3.834% | 3.859% | 15.865% | 15.896% | -3.560% | -3.581% | -0.368% | -0.370% | 21.044% | 21.115% |
| **4. Electrical energy, gas and water** | 4.726% | 5.727% | 16.971% | 18.215% | -4.372% | -5.280% | -0.452% | -0.548% | 23.383% | 26.016% |
| **5. Food** | 0.301% | 0.426% | 0.336% | 0.476% | -0.277% | -0.390% | -0.029% | -0.041% | 0.705% | 1.004% |
| **6. Textile** | 0.390% | 0.517% | 0.436% | 0.577% | -0.359% | -0.471% | -0.037% | -0.050% | 0.915% | 1.219% |
| **7. Manufacture of wood and cork** | 0.275% | 0.358% | 0.307% | 0.400% | -0.254% | -0.328% | -0.026% | -0.034% | 0.644% | 0.841% |
| **8. Paper** | 0.368% | 0.500% | 0.411% | 0.558% | -0.339% | -0.456% | -0.035% | -0.048% | 0.863% | 1.178% |
| **9. Chemistry** | 0.831% | 1.000% | 0.928% | 1.116% | -0.769% | -0.921% | -0.080% | -0.096% | 1.943% | 2.343% |
| **10. Rubber and plastic products** | 0.451% | 0.599% | 0.504% | 0.669% | -0.416% | -0.547% | -0.043% | -0.058% | 1.058% | 1.410% |
| **11. Other non-metallic mineral products** | 1.770% | 2.207% | 1.975% | 2.464% | -1.638% | -2.035% | -0.170% | -0.212% | 4.135% | 5.170% |
| **12. Metal** | 0.254% | 0.336% | 0.284% | 0.375% | -0.234% | -0.307% | -0.024% | -0.032% | 0.595% | 0.792% |
| **13. Machinery** | 0.138% | 0.197% | 0.154% | 0.220% | -0.127% | -0.180% | -0.013% | -0.019% | 0.323% | 0.463% |
| **14. Electrical equipment, electronics and optics** | 0.174% | 0.238% | 0.194% | 0.266% | -0.160% | -0.218% | -0.017% | -0.023% | 0.406% | 0.560% |
| **15. Manufacture of transport material** | 0.193% | 0.271% | 0.215% | 0.302% | -0.177% | -0.247% | -0.018% | -0.026% | 0.451% | 0.637% |
| **16. Other industries** | 0.329% | 0.440% | 0.368% | 0.491% | -0.304% | -0.402% | -0.031% | -0.042% | 0.772% | 1.036% |
| **17. Construction** | 0.537% | 0.847% | 0.599% | 0.945% | -0.496% | -0.778% | -0.051% | -0.143% | 1.255% | 1.986% |
| **18. Commerce** | 0.437% | 0.776% | 0.487% | 0.866% | -0.402% | -0.708% | -0.042% | -0.076% | 1.023% | 1.828% |
| **19. Hotel management** | 0.468% | 0.781% | 0.523% | 0.872% | -0.430% | -0.710% | -0.045% | -0.075% | 1.099% | 1.845% |
| **20. Transport and communications** | 0.923% | 1.399% | 1.030% | 1.562% | -0.853% | -1.287% | -0.088% | -0.135% | 2.157% | 3.281% |
| **21. Financial intermediation** | 0.172% | 0.324% | 0.192% | 0.361% | -0.159% | -0.295% | -0.016% | -0.032% | 0.404% | 0.763% |
| **22. Real estate activities and entrepreneurial services** | 0.206% | 0.434% | 0.230% | 0.485% | -0.190% | -0.397% | -0.020% | -0.045% | 0.483% | 1.021% |
| **23. Public services** | 0.513% | 0.669% | 0.572% | 0.748% | -0.471% | -0.609% | -0.049% | -0.065% | 1.203% | 1.580% |
| **24. Education** | 0.238% | 0.323% | 0.266% | 0.361% | -0.219% | -0.294% | -0.023% | -0.032% | 0.558% | 0.762% |
| **25. Sanitary and veterinary activities; social services** | 0.282% | 0.423% | 0.315% | 0.472% | -0.260% | -0.385% | -0.027% | -0.041% | 0.662% | 0.998% |
| **26. Other services and social activities; personal services** | 0.463% | 0.733% | 0.517% | 0.818% | -0.426% | -0.667% | -0.044% | -0.072% | 1.086% | 1.729% |
| **27. Homes that employ domestic staff** | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |

***Situation 1:*** 10% tax on energy uses
***Situation 2:*** 10% reduction in energy production
***Situation 3:*** 10% reduction in energy uses
***Situation 4:*** 10% tax on energy uses and 10% reduction in energy uses
***Situation 5:*** 10% tax on energy uses and 10% reduction in energy production

**Table 2: Changes in aggregated variables**

| Sectors | Situation 1 | | Situation 2 | | Situation 3 | | Situation 4 | | Situation 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Competitive** | **Mark-up** | **Competitive** | **Mark-up** | **Competitive** | **Mark-up** | **Competitive** | **Mark-up** | **Competitive** | **Mark-up** |
| **Consumption prices:** $p_c$ (%) | 0.510% | 0.746% | 0.922% | 1.188% | -0.470% | -0.683% | -0.049% | -0.071% | 1.565% | 2.131% |
| **Energy uses:** $X'_E$ (%) | -12.820% | -13.242% | -17.452% | -17.904% | -6.281% | -5.820% | -17.845% | -17.805% | -28.517% | -29.295% |
| **Public revenue:** ***R*** **(millions of euro)** | 1,068,355 | 1,072,083 | ----- | ----- | ----- | ----- | 1,041,972 | 1,041,619 | 1,158,645 | 1,168,060 |
| **Changes in welfare:** $\Delta W$ **(millions of euro)** | -460,479 | -673,536 | -832,186 | -1,072,357 | 424,721 | 616,470 | 44,014 | 64,105 | -1,412,557 | -1,923,376 |

***Situation 1:*** 10% tax on energy uses
***Situation 2:*** 10% reduction in energy production
***Situation 3:*** 10% reduction in energy uses
***Situation 4:*** 10% tax on energy uses and 10% reduction in energy uses
***Situation 5:*** 10% tax on energy uses and 10% reduction in energy production