Exogenous Income Determination in a SAM Model: the Catalan Economy towards the "20-20-20 European Directive"

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Abstract

At the end of 2008, the European Union (EU) signed the "20-20-20 European Directive", which is a climate change agreement that pledges to reduce the Union's greenhouse gas emissions by 20% before 2020. Additionally, this agreement also stipulates that 20% of the energy used in Europe has to come from renewable sources, and that energy efficiency has to be improved by 20%. The objective of this paper is to quantify the economic impact of an adaptation of the Catalan emissions to the European regulation through the use of a multisectorial model based on a social accounting matrix (SAM) database. Specifically, we extend the exogenous determination of input-output production to a SAM framework to show the reduction in the level of endogenous income of the model needed to reduce emissions by 20%. With this analysis we quantify the degree of adjustments in the economic agents if the emissions levels are reduced to the level established by the EU policy. Our results suggest that the reduction in the income of those more polluting agents, would succeed in reducing total CO_2 equivalent emissions. This would enable us to comply with the agreement signed by the European Union. However, despite these positive effects to the atmosphere, the economic impacts would be very distorting and very asymmetric individually on the different agents involved.

Keywords: SAM model, greenhouse emissions, regional income, "20-20-20 European Directive".

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1. Introduction

One of the main social and scientific concerns in the last few years has been climate change. It is a problem that affects the whole world and, in fact, the solution requires an international response. We have to remember that not only it is an environmental phenomenon; it can also have important economic and social consequences.[3]

In 2007 this issue became one of the main social and scientific priorities, especially when governments began to intervene more directly. At the end of 2008, the European Union (EU) signed a climate change agreement and pledged to reduce the Union's greenhouse gas emissions by 20% before 2020.[4] There are several sources of greenhouse gas emissions: burning fossil fuels to generate electricity, transport, industrial processes, agriculture, tourism, housing, etc. These gases are, therefore, closely linked to our model of society and our energy consumption.[5] Moreover, this agreement also stipulated that 20% of the energy used had to come from renewable sources, and that energy efficiency had to be improved by 20%.[6]

The measures established to reduce emissions were that sectors causing the most pollution, covered by the European Union Emission Trading Scheme (ETS), will have to reduce their emissions by 21% in relation to 2005; the remaining sectors, such as transport and housing, by 10%. In order to prevent the sectors that pollute to an extreme, and therefore worst hit by the emissions trading rights auction, from taking their factories out of the EU and causing massive job losses, provisions have

[3] As the Stern Review (2006) concluded, "a shared vision of the objectives must exist, and consensus must be reached on action frameworks". It must be based on a shared vision of long-term goals and agreement on frameworks that will accelerate action.

[4] Each country has "its" compulsory national objective established in relation to their emission levels in 2005. Central European countries, still in the economic recovery stage, may increase their emissions, but with certain restrictions. The wealthy EU countries, in contrast, will have to reduce their emissions. No country may reduce its emissions by more than 20%, nor increase them by more than 25%.

[5] Taking into account greenhouse gas emissions in the whole world in 2000, two thirds are generated by energy use—24% in the generation of electricity, 14% in industry, 14% in transport, 8% in buildings, and 5% in other energy-related activities—while a third corresponds to other emission sources—18% to land use, 14% to agriculture, and 3% to waste products (Stern's calculation, 2006; based on data from the World Resources Institute).

[6] The EU also established a specific objective for bio fuels, which should represent at least 10% of the total fuel and diesel oil consumption in transport.

been made to grant 100% of emission rights free to those exceeding a specific threshold.

For countries outside the ETS system, a reduction objective has been assigned on the basis of GDP.[7] In addition, from 2013 onwards, industries will begin to pay to acquire most of their emission trading rights, instead of receiving them free from the State, as has occurred up to now.[8] Thus, many trading permits will be auctioned, but 88% of the revenue from auctioning trading permits will end up in national treasuries to finance the development of renewable energies and 10% will be used to create a solidarity mechanism: part of this money will be set aside for countries lacking development in renewable energies. And the remaining 2% will be assigned to nine East European countries as a supplementary financial aid to back energy enterprises.

In the case of Spain, 20% of the energy consumed will have to come from renewable sources by 2020 (8.7% in 2005). Moreover, 10% of emissions will have to be reduced in sectors not covered by the Emission Trading Scheme —such as transport, housing, agriculture and livestock farming, or waste treatments— in relation to the levels in 2005 (reference year). Sectors covered by the ETS must reduce their emissions by 21% in 2020, also taking 2005 as the reference year.[9]

In this context, it is true that many enterprises will have to cover the costs, but they will also obtain benefits and will be more competitive if they can save energy or develop low carbon production. Therefore, climate change also represents an opportunity to improve, not so much standards of living, but quality of life.[10] Nevertheless, the introduction of measures by

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[7] In this way, the richest countries will have to reduce their greenhouse gas emissions by up to 20%. And the poorest will be able to increase them by up to 20%.

[8] The EU Emission Trading Scheme is a system that enables enterprises to exchange CO_2 emission allowances (also known as "polluting permits"), which will be payments to encourage enterprises to adapt to EU environmental regulations as of 2013. The first sector to pay these allowances in full will be the electricity sector, followed progressively by the aviation, the aluminium and ammonia manufacturing and the petrochemical sectors, among others.

[9] According to the Kyoto Protocol, before 2012 the EU must reduce its greenhouse gas emissions by 8% in relation to 1990. By ratifying the Kyoto Protocol, Spain pledged not to increase greenhouse gas emissions in the period 2008–2012 by more than 15% in relation 1990 levels, but it is one of the countries that has increased carbon production most—as much as 45%.

[10] According to José Manuel Barroso (2008): "If we just continue as before, by 2030 world energy demand will be 50 per cent higher than today and global carbon dioxide emissions

EU member states, such as ecological taxes on the use of polluting products, has not been ruled out.

In the Stern Review (2006), one of the basic elements proposed to control greenhouse gas emissions efficiently, and which currently involves less sacrifice, is to set a price on carbon by means of taxes, trade or regulation. Secondly, promoting technology policies, support for innovation and the deployment of low carbon technologies have also been considered. And finally, barriers to technological change can be eliminated in order to adopt clean technologies, promote energy efficiency and make people aware of possibilities for action in the face of climate change.[11]

Taking into account the 2008 European agreement affecting greenhouse pollution and energy saving, the objective of this paper is to quantify the economic impact of an adaptation of the Catalan emissions to the European regulation. To accomplish with this objective, we use a multisectorial model based on a social accounting matrix (SAM) to analyse the impact on Catalan income (production, factorial income, and private income) of the implementation of policies that would reduce regional CO_2 emissions. In particular, the approach used allows to quantify how much reduction in regional income it is needed to get a significant reduction in pollutant emissions in accordance with the EU agreement.

In recent years, SAMs have become extremely useful tools for the economic analysis. They first appeared in the studies by Stone (1978) and Pyatt and Round (1979), and since then, other studies have shown the

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will have risen by nearly 60 per cent. Our citizens are already witnessing dramatic price increases of energy today. If we have the courage to change, we can slash our oil and gas import bill by 50 billion euros by 2020. We can cut our external dependency on oil and gas and increase our energy security. A Europe that depends less on carbon, with a stronger renewable energy component, is of course also more secure from any possible problem of energy supply. [...] The new climate-friendly economy is a major economic opportunity for Europe. Globally, the overall value of the low carbon energy sector could be as high as 3 trillion dollars per year worldwide by 2050, and it could employ more than 25 million people. Alone the global carbon market, which our EU Emissions Trading Scheme has pioneered, is already worth 20 billion euros a year today and it could be worth twenty times that by 2030. So building a low carbon economy offers the chance to create thousands of new businesses, hundreds of thousands of new jobs and a vast new export market on which Europe can be a world leader".

[11] As the Stern Review (2006) has stated: "… if we wish to reduce the seriousness of the negative effects, adaptation measures are especially urgent in poor countries, the most vulnerable to climate change. If the measures to be taken are regarded as a reasonable cost to "insure ourselves" against the worst effects of climate change, we may possibly still be in time to prevent the worst risks".

usefulness of these databases. A SAM provides a great deal of empirical information and it shows all the transactions occurring among the stakeholders of a specific economic system and, in addition, it shows the existing relationship between income distribution, consumer patterns and the production structure.

The present paper extends the exogenous determination of production in the input-output model (Miller and Blair, 1985) to a SAM database. Despite the usefulness of this method for policy analysis purposes, in what we know, the literature does no contain any application of the income exogenous setting-up to the social accounting matrix model. This approach can be used to show the reduction in the level of income needed to reduce emissions in an exogenously determined quantity. With this analysis, therefore, we can quantify the degree of adjustments in the economic agents if the emissions levels are reduced to the levels established by the EU policy.

The model quantifies different economic impacts on regional income of alternative policy measures that can reduce greenhouse emissions. In fact, policy makers have a set of possible economic and environmental policies that may help to comply with the 20%-20%-20% Directive signed by the European Union. Taking into account the interesting direction of the recent European environmental objectives, the present chapter is an intend of simulate some aspects that can be in line with the European directives.

The rest of the paper is organised as follows. The next section presents the SAM quantity model in which some variables are exogenously fixed. Section 3 describes the national accounting matrix with environmental accounts (NAMEA) for the Catalan economy that has been used in the empirical application, and Section 4 contains the empirical results. The paper ends with a conclusion section.

2. The SAM Model: Exogenous Determination of Total Income

The linear SAM model shows the released effects generated in the economic activity of the various agents with a perspective of the circular flow of income. The relations captured by this model incorporate the interdependences within the productive sphere, the decisions of final demand, and the operations of income distribution. SAM models are based on the calculation of countable or extended multipliers that quantify global effects, in terms of increase in income, produced by the economic system through the income instruments with an exogenous character. By analysing the extended multipliers, it is possible to determine which agents have the greatest effect on the economic activity and which have the smallest.

The origins of this method are found in the pioneering works of Stone (1978) and Pyatt and Round (1979), which showed the relationships between production, income, and demand using a SAM of the Sri Lankan economy. Defourny and Thorbecke (1984) proposed a complementary analysis to traditional multipliers: the structural-path analysis. This contribution shaped not only the influence but also the transmission channels of the multiplier effects between the various agents in the economy.

The general expression of the SAM model is:

$$Y = (I - A)^{-1} X, \tag{1}$$

where Y is the vector of endogenous income in every account, I is the identity matrix, A is a matrix of structural coefficients (calculated by dividing the transactions in the SAM by total endogenous income) and X is the vector of exogenous income. In expression (1), $(I - A)^{-1}$ is the matrix of SAM multipliers. The elements in this matrix, α_{ij}, show the overall effects (direct and indirect) on the endogenous accounts caused by unitary and exogenous changes in the exogenous income of accounts.

Within the structure of a SAM, accounts that represent potential tools of economic policy or variables determined outside the economic system are traditionally considered exogenous. The usual endogeneity assumption in SAM models follows the Pyatt and Round (1979) criteria, which consider sectors of production, factors (labour and capital), and private consumers as endogenous components. On the other hand, the government, the saving-investment account and the foreign sector are considered exogenous components. This assumption therefore captures the complete relationships taking place within the circular flow of income and shows the connections between productive income, factorial and personal distribution of income, and consumption patterns. The SAM model is similar to the input-output model but with a clear difference: in the process of income creation, the extended multipliers incorporate not only the production relations but also the relations of income distribution and final demand.

The basic interpretation of the elements in the multipliers matrix, α_{ij}, is that they translate a change in exogenous demand for a particular account *j*, (X_j), into a change in endogenous income of sector (Y_i) ;[12]

$$\alpha_{ij} = \frac{\Delta Y_i}{\Delta X_j};$$
$$\Delta Y_i = \alpha_{ij} \Delta X_j.$$

It would be slightly cumbersome but completely accurate to call α_{ij} an exogenous demand to endogenous income multiplier. We consider α_{jj} the on-diagonal element in the *jth* column of the multipliers matrix. If we use the same interpretation, we can define:

$$\alpha_{jj} = \frac{\Delta Y_j}{\Delta X_j};$$
$$\Delta Y_j = \alpha_{jj} \Delta X_j.$$

Suppose that we define α_{ij}^* as the ratio of α_{ij} to α_{jj}, that is:

$$\alpha_{ij}^* = \frac{\alpha_{ij}}{\alpha_{jj}} = \frac{\left[\dfrac{\Delta Y_i}{\Delta X_j}\right]}{\left[\dfrac{\Delta Y_j}{\Delta X_j}\right]} = \frac{\Delta Y_i}{\Delta Y_j};$$
$$\Delta Y_i = \alpha_{ij}^* \Delta Y_j.$$

Thus, α_{ij}^* could be termed an income-to-income multiplier. We consider the matrix of these multipliers, $\left(I - A^*\right)^{-1} = \left[\alpha_{ij}^*\right]$ found by dividing each element in a column of $(I - A)^{-1}$ by the on-diagonal element of that column. Then, each

[12] This approach is apparently first discussed in Evans and Hoffenberg (1952) and again in Ritz and Spaulding (1975).

of the elements in column j of $\left(I - A^*\right)^{-1}$ indicates by how much the income of that sector (the row label) would change if the income of sector j changed by one euro. Suppose that sector j increase its output to some amount, $\overline{Y_j}$. Then, post multiplication of $\left(I - A^*\right)^{-1}$ by a vector $\overline{Y}$, with $\overline{Y_j}$ as its *jth* element and zeros elsewhere, will generate a vector of total income necessary from each sector in the economy because of the exogenously determined income of sector j. That is:

$$Y = \left(I - A^*\right)^{-1}\overline{Y} \ . \qquad (2)$$

This expression allows to calculate how much income is needed to satisfy some level of fixed income that can be established a priori.

Our objective is to analyse the effects of reducing the emissions in the most polluting agents of the Catalan economy. To accomplish with this objective, we need to calculate pollutant emissions. Let B be the matrix of greenhouse gas emissions per unit of endogenous income. In this matrix, each element (b_{kj}) is the amount of gas type k (in physical units) per monetary unit of endogenous income in endogenous account j. That is:

$$B = E(\hat{Y})^{-1}, \qquad (3)$$

where E is a matrix of total greenhouse emissions made by the endogenous accounts of the model (i.e. activities of production, factors and consumers),[13] and $\hat{Y}$ is the diagonal matrix of the elements of vector Y of endogenous income. Following equation (3), we can obtain the pollutant emissions as:

$$E = B\hat{Y}, \qquad (4)$$

which means that there is a linear and fixed relation between emissions and endogenous income in the SAM model.

[13] We have rescaled all the gas emissions to show tonnes of CO_2 equivalent.

The simulation analysis involves alternative situations to show the effects of the reduction in the regional pollutant emissions. All the simulations implemented are defined in accordance to the relative importance of the emissions caused by each economic agent. That is, the reduction in emissions that we analyse occurs in the sectors that have the highest relative contribution to total greenhouse emissions of the regional economy. To accomplish with this objective, we define the row vector g of dimension (1x*j*) that shows the relative index of emissions in each endogenous account:

$$g = \frac{e'E}{e'E\overline{e}}, \qquad (5)$$

where e' is a unitary row vector with dimension ($1\times k$), *E* is the matrix of sectorial emissions and $\overline{e}$ is a column unitary vector of dimension ($j\times 1$).[14]

The new emissions associated to the simulations (E^s) are calculated as follows:

$$E^S = B\hat{Y}^S, \qquad (6)$$

where $\hat{Y}^S$ is the diagonal matrix of the new values of endogenous income of the accounts.

Following expression (2), in the simulation analysis we determine an exogenous level of income $\overline{Y}$ that satisfies a 20% reduction in the level of emissions of the sectors which produce most CO_2 relative emissions, according to expression (6).

The definition of measures that affect the individual agents differently seems to be more efficient than a general intervention that affects agents equally. If agents exert different damages to environment, it is necessary to treat them individually to accomplish the environmental objectives with the minimum negative effects on economic activity.

[14] Note that the calculation of g involves the addition of all the gas emissions of each endogenous account through the product $e'E$. This addition is possible because all the emissions are measured in tonnes of CO_2 equivalent.

3. Database

In the empirical application, we used a national accounting matrix with environmental accounts for the Catalan economy with 2001 data. A NAMEA contains the information reflected in a SAM and its links with the environment, that is, it includes both economic and environmental information of an economy. A SAM does not include environmental variables such as polluting emissions, waters or soil, and hazardous waste, the use of natural resources, or environmental quality. A NAMEA extends the SAM framework with environmental information in order to describe how economic activities affect the environment.

The construction of the database involved two phases. First, we compiled the economic information and used it to make up the regional SAM. Second, we added information on regional pollutant emissions to obtain the NAMEA.

Certain statistical information is essential for constructing a SAM. This includes the relations of the productive system (i.e. an input-output table) and the operations of income distribution between factors and institutions (i.e. the national or regional accounts of the economy). Constructing a regional SAM often involves statistical difficulties in obtaining certain variables. Completed homogenous sources are sometimes not available. Other times the information only partially covers what is needed or simply does not exist. Solving these problems requires indirect calculations and assumptions for the regional variables not provided by the statistical information.

The statistical sources used to construct the Catalan SAM database are:

- *The Input-Output Table of Catalonia in 2001* (IDESCAT, 2007).[15] The input-output framework captures the economic relations between the activities and their main economic operations: production, intermediate consumption, private consumption, investment, and exports.

[15] The European System of National and Regional Accounts of 1995 (SEC-95) was used as methodological reference for constructing the input-output table of Catalonia. The SEC-95 is a suitable countable framework to make a systematic and detailed description of an economy as a whole, its components and its relations with other economies.

- *The Regional Accounting of Spain* (INE, 2001). This source provides the main economic relations between Spain and the Catalan economy.

Our database comprises twenty-seven production activities and two factors of production: labour and capital. It also includes a consumer account, a public sector that collects taxes (production taxes, product taxes and direct income taxes) and makes government consumption and public transfers to consumers and businesses. The saving-investment account shows gross fixed capital formation and private savings intended to finance regional investment. Finally, the SAM contains a consolidated account for foreign agents of the Catalan economy.

To build the national accounting matrix with environmental accounts for Catalonia we needed some environmental information that it is essential for empirical modelling and is often difficult to obtain at the regional level. Our NAMEA integrates the SAM database with the Satellite Account on Atmospheric Emissions (IDESCAT, 2008). Our database is therefore applied to atmospheric emissions and is constructed by adding columns related to the greenhouse gas emitted by production activities and consumption.[16]

The information in the account on atmospheric emissions includes the discharges of pollutants generated by sectors and consumption. This database originally included the emissions of eleven pollutants. In this paper, we used only the four emissions that show greenhouse pollution in the regional economy. The four gases we analysed are those that must follow the guidelines of the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrogen monoxide (N_2O) and sulphur hexafluoride (SF_6). The original units of these four emissions have been rescaled so they are all expressed in the same units, which are carbon dioxide equivalents.

4. Empirical Results

This section illustrates the results of the model presented above. The empirical application to Catalan economy incorporates the traditional

[16] See Llop and Pié (2009) for a detailed description of the NAMEA database used in the empirical application.

criterion of endogeneity of accounts.[17] This criterion includes as endogenous components of the model the sectors of production, the factors of production and the households of the economy. Therefore, our model considers 30 endogenous accounts: 27 sectors of production, 2 factors (capital and labour) and 1 representative consumer.

4. 1. Relative Emissions

The simulation analysis has been individually applied in accordance with the relative contribution of greenhouse emissions made by each account. Following expression (5), table 1 shows the relative index of emissions of the endogenous accounts. This calculation enables us to understand the relative importance of each agent in the amount of regional greenhouse pollution.

Households cause the highest contribution to total CO_2 equivalent emissions in Catalonia, since they produce 20.560% of the total greenhouse pollution. The sectors of production that have a significant role are other non-metallic mineral products (sector 11), with 18.439% of the total, and transport and network (sector 20), with 14.953%. We can also highlight, however, agriculture (sector 1), which produces 12.188% of the total, as well as the energy sectors (sector 3 and sector 4), the chemical sector (sector 9) and the other services and social activities; personal services (sector 26), which produce 10.440%, 5.368%, 6.067% and 5.319% of total emissions, respectively. It should be highlighted that the remaining sectors of production are responsible of low emissions, being less than 1% of the total. Finally, note that in table 1 homes that employ domestic staff (sector 27) and factors of production (labour and capital) have null values. This is due to the information in the regional NAMEA, that does not contain greenhouse emissions for these three accounts.

[PLACE TABLE 1 HERE]

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[17] See Stone (1978) and Pyatt and Round (1979).

The results of table 1 suggest that air emissions are concentrated in a few sectors of production which, together with households, are responsible of the major part of total pollution. It is interesting to remark that the relative importance of three accounts (households, non-metallic products (sector 11) and transport and communications (sector 20)), amounts approximately 54% of the regional greenhouse pollution. This fact may mean that pollution abatement policies must be individually defined and individually applied to generate a minimum distortion on the economic and productive system.

4.2. Quantity Effects of a 20% Reduction in Sectorial Greenhouse Emissions

As we saw in table 1, the agents which produce most CO_2 equivalent emissions are agriculture (sector 1), energy, minerals, coke, petroleum and fuels (sector 3), other non-metallic mineral products (sector 11), transport and communications (sector 20), and households. This observation led us to the question of what amount it would be necessary to reduce the final production of the different production activities and the income of the factors of production and consumers so as to give rise to a 20% reduction in the CO_2 equivalent emissions of sector 1, sector 3, sector 11, sector 20 and households.

In the empirical application, we extended the input-output model proposed by Miller and Blair (1985) to a SAM framework, following expression (2). Specifically, in the simulations, there is analysed a fixed level of income ($\overline{Y}$) that satisfies the desired reduction in the level of emissions according to expression (6). The analysis involves five different scenarios. In the first one, we analysed by what amount the endogenous accounts would need to reduce their level of income to give rise to a 20% reduction in the CO_2 equivalent emissions of agriculture (sector 1). In subsequent scenarios we applied exactly the same changes so as to reduce the emissions in energy, minerals, coke, petroleum and fuels (sector 3), other non-metallic mineral products (sector 11), transport and communications (sector 20) and households.

Table 2 shows the changes in total income and in CO_2 equivalent emissions in each simulation. The first column shows by what amount it would be necessary to reduce the final production of the various production activities, the factorial income and the private income to enable agriculture (sector 1) to reduce its CO_2 equivalent emissions by 20%; as we can see, in order to achieve this objective sectorial production would have to be reduced by between 15% and 26%. The most noteworthy case is that of households, in which case a reduction in final production of 25.95% would be required. Apart from this, transport and communications (sector 20) would need to reduce its final production by 25.72%, textile (sector 6) by 25.58%, real estate and entrepreneurial services (sector 22) by 24.92%, and agriculture (sector 1) by 24.35%. The CO_2 equivalent emissions would reduce by 23.36%, which would enable us to comply with the agreement on climate change signed by the European Union in late 2008, in which an undertaking was given to reduce emissions of greenhouse effect gases by 20% by the year 2020.

In the following column, energy, minerals, coke, petroleum and fuels (sector 3) would reduce its CO_2 equivalent emissions by 20%. The application of this simulation gives results that are fairly similar to those of the previous one: energy, minerals, coke, petroleum and fuels (sector 3) would need to reduce its final production by 26.75%, households by 25.66%, textile (sector 6) by 22.52%, and real estate and entrepreneurial services (sector 22) by 24.84%. CO_2 equivalent emissions would be reduced by 23.22%, and we would thus also comply with the EU agreement.

In the following scenario, the emissions are reduced in other non-metallic mineral products (sector 11), and it is observed that all production activities, factors of production and households are affected between 15% and 25% in order to obtain the reduction in emission of sector 11. Sectors more affected would be households, with 25.85%, transport and communications (sector 20) with 25.74%, textile (sector 6) with 25.56% and real estate and entrepreneurial services (sector 22) with 24.88%. Additionally, total emissions would be reduced by 23.66%.

In the fourth scenario, emissions of transport and communications (sector 20) are reduced by 20%. Once again the results show a wide range of percentage variation, machinery (sector 13) is the sector which would need to least reduce (by 15.47%) its final production in order to meet the proposed objective, while transport and communications (sector 20) would need the largest reduction (by 30%). In addition, households would reduce their income by 26.28%, textile (sector 6) would reduce its production income by 25.78%, and real estate and entrepreneurial services (sector 22) by 25.25%. In this situation, total emissions would reduce by 23.76%.

The last scenario reduces private emissions by 20%. In this simulation, households and transport and communications (sector 20), are the most affected with reductions of 29.20% and 27.50% in its income, respectively. With regard to other sectors, textile (sector 6) would need to have a reduction of 27.30%, real estate and entrepreneurial services (sector 22) a reduction of 26.80%, and hotel management (sector 19) of 26.54%. In this scenario, the reduction in total CO_2 equivalent emissions (24.88%) is greater than in the preceding scenarios.

[PLACE TABLE 2 HERE]

The conclusions that we can draw from table 2 are that by applying the reductions in the emissions of the sectors that pollute most we would succeed in reducing total CO_2 equivalent emissions between 23% and 25%, which would enable us to comply with the agreement signed by the European Union. Despite these positive effects to the atmosphere, the economic impacts would be very distorting and very asymmetric individually on the different agents involved.

5. Conclusions

In this paper we have used a quantity-based SAM model, through which we analyse different measures that would help us to reduce CO_2 equivalent emissions in those sectors that produce most of the Catalan emissions. The simulations in the paper go in line with the "20-20-20 European Directive" that pledges to reduce the Union's greenhouse gas emissions by 20%

before 2020 and stipulates that 20% of the energy used in Europe has to come from renewable sources and that European energy efficiency had to be improved by 20%.

Having observed the relative index of emissions for each endogenous account and identified that the sectors producing most CO_2 equivalent emissions, we analysed the amount by which it would be necessary to reduce the final production of the different production activities, factors of production and consumers in order to ensure that the most polluting agents reduce individually their CO_2 equivalent emissions by 20%.

Our results show that total CO_2 equivalent emissions would reduce between 23% and 25%, and would therefore comply with the agreement on climate change signed by the European Union in late 2008. However, the economic effects of such accomplishment would force to reduce endogenous income in a greater extend. This would make these measures impracticable in practise. These results can, however, be used to find solutions for fighting against climate change, since policy makers can use the results to design appropriate policies to reduce CO_2 equivalent emissions. It also can used to capture the individual effects on the different agents involved. Although it may at first seem that some measures are not very favourable for households and for certain production activities, which would be obliged to reduce significantly their production levels, in the long term they would in fact be extremely beneficial for the Catalan economy and society at large.

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Table 1. Relative index of emissions (*g*)

	(%)
1. Agriculture	12.188%
2. Fishing	0.182%
3. Energy, minerals, coke, petroleum and fuels	10.440%
4. Electrical energy, gas and water	5.368%
5. Food	1.014%
6. Textile	0.567%
7. Manufacture of wood and cork	0.136%
8. Paper	0.733%
9. Chemistry	6.067%
10. Rubber and plastic products	0.261%
11. Other non-metallic mineral products	18.439%
12. Metal	0.992%
13. Machinery	0.160%
14. Electrical equipment, electronics and optics	0.249%
15. Automobiles	0.342%
16. Other industries	0.215%
17. Construction	0.264%
18. Commerce	0.521%
19. Hotel management	0.188%
20. Transport and communications	14.953%
21. Financial intermediation	0.054%
22. Real state activities, entrepreneurial services	0.384%
23. Public services	0.109%
24. Education	0.065%
25. Sanitary, veterinary activities, social services	0.230%
26. Other services, social and personal services	5.319%
27. Homes that employ domestic staff	0.000%
Labour	0.000%
Capital	0.000%
Households	20.560%

Table 2. Changes in endogenous income (%)

	Situation A	Situation B	Situation C	Situation D	Situation E
1. Agriculture	-24.35%	-20.44%	-20.48%	-20.71%	-22.40%
2. Fishing	-20.84%	-20.76%	-20.80%	-21.10%	-23.26%
3. Energy, minerals, coke, petroleum and fuels	-22.64%	-26.75%	-22.88%	-23.37%	-24.13%
4. Electrical energy, gas and water	-20.64%	-20.55%	-20.65%	-21.03%	-22.53%
5. Food	-23.27%	-23.05%	-23.10%	-23.35%	-25.26%
6. Textile	-25.58%	-25.52%	-25.56%	-25.78%	-27.30%
7. Manufacture of wood and cork	-22.21%	-22.18%	-22.30%	-22.38%	-23.26%
8. Paper	-24.22%	-24.16%	-24.21%	-24.48%	-25.51%
9. Chemistry	-22.24%	-22.13%	-22.20%	-22.30%	-23.09%
10. Rubber and plastic products	-17.16%	-17.11%	-17.17%	-17.38%	-18.14%
11. Other non-metallic mineral products	-16.59%	-16.62%	-23.94%	-16.74%	-17.37%
12. Metal	-19.95%	-19.95%	-19.99%	-20.11%	-20.67%
13. Machinery	-15.32%	-15.29%	-15.34%	-15.47%	-16.22%
14. Electrical equipment, electronics and optics	-18.98%	-18.94%	-18.97%	-19.26%	-20.10%
15. Manufacture of transport material	-22.30%	-22.25%	-22.28%	-22.59%	-23.78%
16. Other industries	-18.54%	-18.49%	-18.53%	-18.78%	-20.35%
17. Construction	-21.15%	-21.30%	-21.20%	-21.43%	-22.09%
18. Commerce	-23.30%	-23.21%	-23.26%	-23.57%	-25.47%
19. Hotel management	-23.85%	-23.77%	-23.82%	-24.18%	-26.54%
20. Transport and communications	-25.72%	-25.66%	-25.74%	-30.00%	-27.50%
21. Financial intermediation	-23.43%	-23.36%	-23.40%	-23.75%	-25.46%
22. Real estate and entrepreneurial services	-24.92%	-24.84%	-24.88%	-25.25%	-26.80%
23. Public services	0.00%	0.00%	0.00%	0.00%	0.00%
24. Education	-18.76%	-18.69%	-18.74%	-19.02%	-20.83%
25. Sanitary, veterinary and social services	-20.11%	-20.04%	-20.08%	-20.34%	-22.22%
26. Other services, social and personal services	-21.31%	-21.24%	-21.29%	-21.58%	-23.60%
27. Homes that employ domestic staff	-22.38%	-22.30%	-22.35%	-22.66%	-25.16%
Labour	-22.41%	-22.35%	-22.42%	-22.80%	-23.88%
Capital	-23.90%	-23.73%	-23.80%	-24.31%	-25.31%
Households	-25.95%	-25.85%	-25.91%	-26.28%	-29.20%
Average income	**-23.63%**	**-23.56%**	**-23.58%**	**-24.05%**	**-25.64%**
Total emissions	**-23.36%**	**-23.22%**	**-23.66%**	**-23.76%**	**-24.88%**

Situation A: 20% reduction in the CO_2 emissions of Agriculture (sector 1).
Situation B: 20% reduction in the CO_2 emissions of Energy, minerals, coke, petroleum and fuels (sector 3).
Situation C: 20% reduction in the CO_2 emissions of Other non-metallic mineral products (sector 11).
Situation D: 20% reduction in the CO_2 emissions of Transport and communications (sector 20).
Situation E: 20% reduction in the CO_2 emissions of Households.