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Document de treball nº -19- 2009

DEPARTAMENT D'ECONOMIA
Facultat de Ciències Econòmiques i Empresarials

Edita:

Departament d'Economia
http://www.fcee.urv.es/departaments/economia/public_html/index.html
Universitat Rovira i Virgili
Facultat de Ciències Econòmiques i Empresarials
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Dirigir comentaris al Departament d'Economia.

Dipòsit Legal: T - 2118 - 2009

ISSN 1988 - 0812

DEPARTAMENT D'ECONOMIA
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The Analysis of Accounting Multipliers: The NAMEA Approach in the Case of Catalonia

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Abstract

The aim of this paper is the analysis of the Catalan economy (2001) with the use of a National Accounting Matrix with environmental accounts (NAMEA) for the Catalan economy with 2001 data. We will focus on the analysis of the emission multipliers and we will also analyse the impact of a 10% reduction in greenhouse emissions on emission multipliers. This emission-reduction percentage would bring the Catalan economy into compliance with the maximum emissions level allowed by the Kyoto Protocol. We consider three possible scenarios that would allow this goal to be met. First, we will simulate a 10% reduction in regional emissions and a 5% drop in the endogenous income of the multipliers' model (production, factorial and private income). Second, we will simulate a 10% reduction in emissions and a 10% increase in endogenous income. Finally, we will simulate a 10% reduction in emissions and a 5% increase in endogenous income. Additionally, we will analyse the decomposition of the emission multipliers into own effects, open effects and circular effects to capture the different channels of the emission generation process.

Keywords: NAMEA, emission multipliers, Kyoto Protocol.

1. Introduction

Nowadays, there is constant economic growth in the industrialized countries, together with an increasing population in the developing countries. This can rise the demand for resources and the negative impacts of economic activity, and is the reason why developing countries have recently expressed concerns about obtaining higher and more equitable economic growth whilst at the same time reducing the associated environmental damage.

There has been much debate in recent times regarding the relation between economic activity and the environment and the measures that need to be taken to preserve the natural habitats. In fact, the environmental deterioration has recently focused the attention of both economists and ecologist that have integrated ideas and concepts. On the one hand economic activities make use of natural resources, and on the other they generate emissions. However, the national accounts systems do not take into account that the environmental data may be related with the mechanisms that determine the circular flow of income. Some experts have proposed the creation of an integrated system of environmental-economic accounting that allows the evaluation of policies designed to attain sustainable development. There are also authors that argue that environmental degradation should appear as a discount factor in the national accounts system. This would permit countries' economic growth to be accurately estimated.

In 1993, the United Nations published the System of National Accounts (United Nations, 1993) in which it was formulated, for the first time, an accounting framework for assessing national accounts and environmental statistics. Afterwards, this integrated system was revised and published in a handbook (United Nations, 2003) that permits a consistent analysis of the environment's contribution to the economy and the economy's impact on the environment.

In addition to the efforts by the United Nations to integrate economic and environmental accounts, studies on incorporating environmental impacts in the social accounting matrix (SAM) framework emerged in the 1990s. For example, Keuning (1992, 1993 and 1994) proposed the development of a national accounting matrix that would include environmental accounts. In this matrix, the economic variables would be expressed in monetary terms and the environmental ones in physical terms.

Subsequently, Xie (1995) constructed an environmental SAM for China that took into consideration polluting emissions.

De Haan and Keuning (1996) presented a National Accounting Matrix including Environmental Accounts (NAMEA) for the Netherlands. Keuning, Dalen and De Haan (1999) described an aggregated NAMEA which they used to compare the contribution of economic activities to economic indicators with the contribution of economic activities to environmental themes. They also described how economic activities contribute cumulatively to economic and environmental indicators (thus taking into account the relations between the production activities) and described a number of recent applications and extensions of the NAMEA in the Netherlands.

Ike (1999) described a NAMEA for Japan which provided a comprehensive and consistent picture of the interrelationship between the economy and the natural environment, a basis on which cost-benefit analysis could be applied and the necessary information for policy planning. This NAMEA showed environmental pressures not only from domestic pollutant emissions, but also from transboundary flows from the rest of East Asia.

Vaze (1999) described how environmental accounts carried out in the UK were calculated. Results from the pilot accounts were reproduced in a NAMEA framework, which allowed the comparisons with the NAMEAs calculated by other countries. Xie and Saltzman (2000) constructed a numerical version of the environmentally extended SAM using Chinese data from 1990. Multiplier and structural-path analyses were applied to this database to assess the environmental impacts of pollution-related economic policies. Xie (2000) then extended the SAM to capture the relationships among economic activities, pollution abatement activities, and pollution emissions. The author presented a numerical example of the environmentally extended social accounting matrix (ESAM) using Chinese data from 1990. Multiplier and structural path analyses were applied to the ESAM to assess the environmental impacts of pollution-related economic policies. The results showed that an integrated economic-ecologic database can be a useful tool for environmental policy analysis.

De Hann and Keuning (2001) showed how environmental issues can be incorporated into macroeconomic accounting trough the construction of a National

Accounting Matrix including Environmental Accounts (NAMEA) for the Netherlands. The paper discussed a number of conceptual issues on the harmonisation of environmental statistics and national accounts. Specific attention was given to consistently accounting for the pollution generated by production and consumption activities and to the importance of aggregated environmental indicators.

For Spanish applications, Manresa and Sancho (2004) conducted the first integrated economic and environmental analysis for Catalonia, taking 1987 as the base year. The paper analysed the sectorial power intensity of the Catalan economy using a regional SAM that differentiated between the polluting emissions originating from production and those originating from final consumption. The authors observed that the energy sectors themselves were the largest consumers of energy sources. Rodríguez, Llanes and Cardenete (2007) showed that a SAM including environmental accounts can be used for economic and environmental efficiency analysis. They used Spanish data for the year 2000 and applied it to water resources and greenhouse gas emissions. Finally, Flores and Sánchez (2007) analysed and the most important environmental impacts on the economy of Aragon by relating the main economic activities to resource consumption and pollution levels. To carry out this analysis, they constructed a Social Accounting Matrix including Environmental Accounts (SAMEA) for Aragon for 1999.

The methods that integrate economic information and environmental effects are very useful for determining the environmental consequences of economic activity. The improvement of databases and linear models will allow the effects of the circular flow of income and the associated environmental loads to be analysed jointly. This area of research captures both environmental and economic aspects of the environmental problems that affect the global economy.

The aim of this paper is to analyse the Catalan economy (2001) with a linear model. We will focus on the analysis of the classic multipliers (Stone-Pyatt and Round) and the associated emission multipliers. To complete the analysis, we also analyse the impact of a 10% reduction in greenhouse emissions on emission multipliers.[1] This

[1] On 23 January 2008, the European Commission met to endorse an action plan to fight climate change known as "20 20 by 2020". This has become the mantra used by the Commission to present itself to the rest of the world as a champion in the fight against climate change. The plan calls for a 20% reduction in CO_2 emissions and the use of 20% of renewable energy sources (with 10% of fuel from biofuel) by 2020. In order to reach these percentages, each country must contribute in proportion to its per capita GDP. Spain will have to obtain 20% of its energy from

emission-reduction percentage would bring the Catalan economy into compliance with the maximum emissions level allowed by the Kyoto Protocol. We consider three possible scenarios that would allow this goal to be met. First, we simulate a 10% reduction in regional emissions and a 5% drop in the endogenous income of the multipliers' model (production, factorial and private income). Second, we simulate a 10% reduction in emissions and a 10% increase in endogenous income. Finally, we simulate a 10% reduction in emissions and a 5% increase in endogenous income. We also analyse the decomposition of the emission multipliers into own effects, open effects and circular effects to capture the different channels of emission generation.

If we wish to decrease the level of polluting emissions but maintain a high standard of living in society, it is essential to analyse the various policies available in order to understand the effects involved. Policies designed to reduce emissions may clash with society's development objectives, since economic growth, the consumption of natural resources, and pollution are closely related. An attempt should be made, therefore, to establish a link between economic activity and environmental impacts in order to ensure sustainable development.

The rest of the paper is organised as follows. The next section describes the linear SAM model. Section 3 presents the decomposition of the multipliers. Section 4 describes the extension of the SAM model with greenhouse emissions and Section 5 analyses the results. The paper ends with a conclusion section.

2. The Linear SAM Model

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 interdependences within the productive sphere, final demand decisions, and income distribution operations.

SAM models calculate countable or extended multipliers that quantify the global effects in terms of increase in income, produced by exogenous income

renewable energy sources by 2020, which is more than twice the current level (8.7% in 2005), and reduce its greenhouse gas emissions by 10%.

instruments. By analysing the extended multipliers, it is possible to determine which agents have the greatest effects on economic activity and which the smallest. In fact, the SAM model is similar to the input-output model, but with one clear difference: the extended multipliers incorporate in the process of income creation not only production relations, but also relations of income distribution and final demand.

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

The starting point in the SAM model is to divide accounts into two types: endogenous and exogenous. Table 1 contains the accounting identities inherent to a SAM in which the accounts have been divided into these two types.

Table 1. Endogenous and exogenous accounts in a SAM

<table>
<tr><td rowspan="2" colspan="2"></td><td colspan="5">EXPENDITURE</td></tr>
<tr><td>Endogenous</td><td>Sum</td><td>Exogenous</td><td>Sum</td><td>Total</td></tr>
<tr><td rowspan="2">INCOME</td><td>Endogenous</td><td>T_{nn}</td><td>n</td><td>Injections
T_{nx}</td><td>x</td><td>$\boldsymbol{Y}$</td></tr>
<tr><td>Exogenous</td><td>Outlays
T_{xn}</td><td>l</td><td>Residual Balance
T_{xx}</td><td>t</td><td>$\boldsymbol{X}$</td></tr>
<tr><td colspan="2">TOTAL</td><td colspan="2">$\boldsymbol{Y}$</td><td colspan="2">$\boldsymbol{Z}$</td><td></td></tr>
</table>

Source: Defourny and Thorbecke (1984)

According to table 1, the sum of the row of endogenous accounts is column vector Y with two different parts: the endogenous accounts (T_{nn}, whose sum is represented by vector n) and the exogenous accounts (T_{nx}, whose sum is represented by vector x). In other words:

$$Y = n + x. \quad (1)$$

The components of the matrix of transactions between endogenous accounts, T_{nn}, can be obtained from the ratios of the corresponding totals in columns:

$$T_{nn} = A\hat{Y}, \quad (2)$$

where $\hat{Y}$ is the diagonal matrix of the elements of vector Y. Similarly, matrix A contains the transactions of each endogenous account in relation to the column total in the SAM $\left(a_{ij} = \frac{T_{ij}}{Y} \right)$.

Vector n can be obtained by using matrix A in the following way:

$$n = AY. \quad (3)$$

By combining expressions (1) and (3), we obtain:

$$Y = n + x = AY + X = (I - A)^{-1} X = MX, \quad (4)$$

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 (4), $M= (I - A)^{-1}$ is the matrix of SAM multipliers. This matrix shows 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, the accounts that represent potential tools of economic policy or variables determined outside the economic system are traditionally considered exogenous. The usual assumption of endogeneity made in SAM models follows the Pyatt and Round (1985) 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 of 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 one clear difference: in the process of income creation, the extended multipliers incorporate not only production relations but also relations of income distribution and final demand.

3. Decomposition of the multipliers

The traditional endogeneity assumption of Stone (1978) and Pyatt and Round (1979) considers activities, factors of production and households to be endogenous components. So, matrix A of structural coefficients has the following structure:

$$A = \begin{bmatrix} A_{11} & 0 & A_{13} \\ A_{21} & 0 & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix},$$

where A_{11} contains the input-output coefficients, A_{13} contains the coefficients of the household sectorial consumption, A_{21} contains the factors of production coefficients, and A_{32} contains the coefficients of factor income of consumers. The SAM model completes the circular flow by capturing not only the intermediate demand relations, but also the relations between factor income distribution and private consumption.

To provide a deeper insight into the analysis of SAM multipliers, Pyatt and Round (1979) divided matrix M into different circuits of interdependence. Specifically, it can be seen that:

$$\begin{aligned} Y &= AY + X \\ &= \left(A - \bar{A}\right)Y + \bar{A}Y + X \\ &= \left(I - \bar{A}\right)^{-1}\left[\left(A - \bar{A}\right)Y + X\right] \\ &= \dot{A}Y + \left(I - \bar{A}\right)^{-1} X \\ &= \dot{A}^2 Y + \left(I + \dot{A}\right)\left(I - \bar{A}\right)^{-1} X \\ &= \dot{A}^3 Y + \left(I + \dot{A} + \dot{A}^2\right)\left(I + \bar{A}\right)^{-1} X \\ &= M_3 M_2 M_1 X, \end{aligned} \qquad (5)$$

where $\dot{A} = \left(I - \bar{A}\right)\left(A - \bar{A}\right)$, $M_1 = \left(I - \bar{A}\right)^{-1}$, $M_2 = \left(I + \dot{A} + \dot{A}^2\right)^{-1}$, and $M_3 = \left(I - \dot{A}^3\right)^{-1}$.

Finally, matrix $\bar{A}$ has the following structure:

$$\bar{A} = \begin{bmatrix} A_{11} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & A_{33} \end{bmatrix}.$$

In the expression above, matrix M of total SAM multipliers has been defined by three multiplicative components that convey different economic meanings.[2] After the corresponding matrix algebra has been applied, it can be seen that the first block M_1 has the following elements:

$$M_1 = \begin{bmatrix} (I - A_{11}) & 0 & 0 \\ 0 & I & 0 \\ 0 & 0 & (I - A_{33})^{-1} \end{bmatrix}.$$

Matrix M_1 contains the own effects explained by the connections between the accounts belonging to the same income relationships. Specifically, the perspective of income transmission reflected in M_1 responds to the effects of intersectorial linkages and the effects of transactions between consumers.

Additionally, matrix M_2 is a follows:

$$M_2 = \begin{bmatrix} I & (I - A_{11})^{-1} A_{13}\, I\, A_{32} & (I - A_{11})^{-1} A_{13} \\ A_{21} & I & A_{21}(I - A_{11})^{-1} A_{13} \\ (I - A_{33}) A_{32}\, A_{21} & (I - A_{33})^{-1} A_{32} & I \end{bmatrix}.$$

This block contains the open effects caused by the accounts on the other parts of the circular flow of income. As it shows the effects of the accounts on the other income circuits of the system, the main diagonal in M_2 is unitary and the other elements are positive.

Finally, matrix M_3 has the following structure:

$$M_3 = \begin{bmatrix} \left[I - (I - A_{11})^{-1} A_{13} (I - A_{33})^{-1} A_{32} A_{21}\right]^{-1} & 0 & 0 \\ 0 & \left[I - A_{21} (I - A_{11})^{-1} A_{13} (I - A_{33})^{-1} A_{32}\right]^{-1} & 0 \\ 0 & 0 & \left[I - (I - A_{33})^{-1} A_{32} A_{21} (I - A_{11})^{-1} A_{13}\right]^{-1} \end{bmatrix}$$

[2] Note that the decomposition in equation (2) is not unique. In consequence, the interpretation of the decomposed multipliers depends basically on the division of the matrix of expenditure share coefficients, that is, the structure of matrix $\bar{A}$.

Block M_3 contains the circular effects on the accounts that are activated because of exogenous inflows. Component M_3 is a block diagonal matrix, showing the closed-loop effects of circular flow caused by the own exogenous shocks on the accounts.

The decomposition of SAM multipliers identifies the channels through which income effects can be produced and transmitted throughout the economy. Logically, this kind of information is very useful for establishing the origin of income shocks on economic agents and institutions, and it provides deeper insights into the circular flow of income.

In order to better interpret the results, we perform an additive decomposition of the multiplier matrix. This decomposition, proposed by Stone (1978), uses an additive formula calculated by a simple transformation of the previous multiplicative division to identify each effect:

$$M = M_3 M_2 M_1 = I + (M_1 - I) + (M_2 - I) M_1 + (M_3 - I) M_2 M_1 . \qquad (6)$$

where I includes the initial injection of income that begins the entire multiplier process, $(M_1 - I)$ shows the net contribution of own effects in net terms, $(M_2 - I) M_1$ quantifies the open net effects and, finally, $(M_3 - I) M_2 M_1$ represents the net contribution of the circular effects.[3]

It should be pointed out that, in addition to this multiplier decomposition process, some authors have proposed alternative analyses. For example, Defourny and Thorbecke (1984) proposed the so-called structural or trajectory analysis.[4] This method observes the paths along which the multipliers travel and has the advantage of obtaining the entire network through which the influence is transmitted, from a source account to a destination account.

The multiplicative decomposition shown does not enable the results to be interpreted immediately. Conversely, the additive decomposition proposed by Stone

[3] There are many examples of this method in the literature. We can cite Bottiroli and Targetti (1988) in the area of income distribution, Khan (1999) in the analysis of poverty, Xie (2000) for topics related to the environment, and de Miguel et al. (1998) and Llop and Manresa (1999) in regional studies.

[4] For an extended view of this method and possible empirical applications, see Crama, Defourny and Gazón (1984); Polo, Roland-Host and Sancho (1991b); Sonis, Hewings and Sulistyowati (1997); Thorbecke (1998); Azis (1999); Ferri and Uriel (2000) and Roberts (2005).

(1978) allows us to use an additive formula to reveal the contribution made by each individual effect to the total multiplier effect using an additive formula.

To obtain the additive division, we use the following transformation of the above expression (6):

$$M - I = (M_1 - I) + (M_2 - I)M_1 + (M_3 - I)M_2 M_1. \qquad (7)$$

This new expression (7) leads to the total net multiplier effect, that is $(M - I)$, which is the result of the aggregation of the own net effects $(M_1 - I)$, the open net effects $(M_2 - I)M_1$ and, lastly, the circular net effects $(M_3 - I)M_2\, M_1$.

4. Extension of the SAM Model with Greenhouse Emissions: the NAMEA Model

The SAM model can be extended to account for the environmental pollution associated with production and consumption activities, which are considered endogenous in the definition of the model. This extension integrates the economic and ecological relations that take place in environmental pollution and is a useful instrument of environmental analysis and control.

Let *B* be the matrix of greenhouse emissions per unit of endogenous income. In this matrix each element is the amount of gas type *i* (in physical units) per monetary unit of endogenous income in account *j*. That is:

$$B = E(\hat{Y})^{-1} = \frac{E}{\hat{Y}}, \qquad (8)$$

where *E* is a matrix of total greenhouse emissions made from the endogenous accounts of the model (i.e. activities of production, factors and consumers), and $\hat{Y}$ is the diagonal matrix of the elements in vector *Y* of endogenous income.

The amount of emissions associated with a given level of exogenous income (*X*) can then be calculated as follows:

$$F = B(I - A)^{-1} X, \qquad (9)$$

where *F* is the vector of *i* greenhouse emissions. The elements in matrix $B(I - A)^{-1}$ are the emission multipliers, which measure the amount of type *i* emissions caused by exogenous and unitary inflows to account *j*. With this approach we can therefore analyse how unitary changes in the exogenous demand (an increase or decrease in investment and exports, for example) affect the amount of greenhouse emissions. This information is valuable for environmental protection since it shows the environmental impacts associated with production activities, factors of production and private consumption.

Taking into account expressions (4), (5), (6) and (7), the NAMEA emission multiplier matrix can be decomposed into:

$$F = BM = B(I - A)^{-1} = BM_3M_2M_1. \qquad (10)$$

According to the additive decomposition of the income multipliers (expressions (6) and (7)), the NAMEA multiplier matrix of polluting emissions can be divided into:

$$F = B(M - I) = B(M_1 - I) + B(M_2 - I)M_1 + B(M_3 - I)M_2M_1. \qquad (11)$$

This expression allows the total net emission multipliers to be obtained: that is to say, $F = B(M - I)$, as a result of aggregating the net own effects $B(M_1 - I)$, the net open effects, $B(M_2 - I)M_1$, and finally, the net circular effects, $B(M_3 - I)M_2M_1$.

The $B(M_1 - I)$ matrix, or the own effects matrix, captures the effects that a group of accounts has on itself as a consequence of internal transfers in the own group.

On the other hand, the $B(M_2 - I)M_1$ matrix captures the net open effects of the multiplier process on the accounts belonging to the other parts of the income flow after income has been injected in each account.

Finally, the $B(M_3 - I)M_2M_1$ matrix shows the circular net effects of an injection of exogenous income that goes through the system and returns to its point of origin.

5. Empirical Application to Catalan Greenhouse Emissions

Our analysis is based on SAM methodology, which reflects the relationships between demand and production, production and income, and income and demand.[5] We also extend these relations to the effects on greenhouse pollution in the regional economy. The analytical framework developed in Section 4 shows how the exogenous and unitary inflows to production activities, factors, and consumers affect greenhouse gas emissions. Therefore, it quantifies how much increase there is in greenhouse emissions when there is a unit of increase in exogenous demand.

The NAMEA for Catalonia, integrates the SAM database described in the section above with the Satellite Account on Atmospheric Emissions (IDESCAT, 2008). Our database is therefore applied to atmospheric emissions and it is constructed by adding columns of the greenhouse gases emitted by production activities and consumption.

The information in the account on atmospheric emissions includes the discharge of pollutants generated by sectors and consumption. This database originally included the emissions of eleven pollutants. As our aim was to model greenhouse effects, we used only the three emissions that show greenhouse pollution in the regional economy. The three 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).

The information provided by the model shows several aspects of greenhouse pollution. We shall first focus on the emission multipliers that quantify the changes in the levels of emissions caused by changes in exogenous inflows.

[5] In contrast, the calculation of multipliers in the traditional input-output model omits the relationships in the circular flow of income from the productive sector towards the primary factors revenue and public or private expenditure. It also omits the feedback effects from these to the productive sectors. Although the input-output model captures the impact of changes in final demand on productive sectors, the chain of events is interrupted at this point since it does not take into account the impact of production on income, consumption and savings.

5.1. Emission Multipliers

In the emission multipliers, sectors, production factors, labour (gross wages and salaries plus social contributions) and capital (the gross operating surplus) were considered as endogenous items. The private sector, which includes consumers, was also considered. Finally, the productive branches are disaggregated into the 27 sectors that appear in our social and environmental accounting matrix.

On the other hand, the savings and investment accounts of the economy (gross capital formation) were considered as exogenous items. The public sector (public administration consumption), net production tax, net product tax, indirect taxes connected with production, import taxes, value added tax and the foreign sector are also exogenous components of the model.

The emission multipliers show how the production sectors and consumers are linked to the pollution they generate. In the SAM model, an increase in exogenous demand leads to an increase in endogenous income. At the same time, the direct relationship between pollution levels and endogenous income means that an increase in the latter increases the former.

In this section we examine how greenhouse gas emissions change in response to exogenous and unitary changes in the exogenous demand for production activities, consumption and factors of production, which are endogenous components in model. We can then identify the agents that cause the highest levels of pollution, which is valuable information for designing policies to reduce greenhouse gases and satisfy the Kyoto Protocol.

Table 2 contains the emission multipliers in matrix $B(I - A)^{-1}$. They show the changes in Catalan emissions when there is an exogenous and unitary inflow to the endogenous accounts (production, factors and consumers). Table 2 should be read as follows: the first row and the first column indicate that when agriculture is subject to an exogenous and unitary increase in its exogenous demand, CH_4 emissions increase by 0.021919 tonnes.

Table 2. Emission multipliers ($B(I - A)^{-1}$)

	CH_4 (t)	CO_2 (kt)	N_2O (t)
1. Agriculture	0.021919	0.000222	0.000865
2. Fishing	0.000590	0.000207	0.000021
3. Energy, Minerals, Coke, petroleum and fuels	0.000757	0.000726	0.000025
4. Electrical energy, gas and water	0.005290	0.000663	0.000038
5. Food	0.005878	0.000205	0.000224
6. Textile	0.001742	0.000190	0.000056
7. Manufacture of wood and cork	0.002932	0.000178	0.000106
8. Paper	0.001314	0.000203	0.000038
9. Chemistry	0.001107	0.000298	0.000041
10. Rubber and plastic products	0.001240	0.000200	0.000037
11. Other non-metallic mineral products	0.001293	0.002071	0.000061
12. Metal	0.000921	0.000162	0.000025
13. Machinery	0.001146	0.000122	0.000025
14. Electrical equipment, electronics and optics	0.000753	0.000123	0.000021
15. Automobiles	0.000921	0.000147	0.000026
16. Other industries	0.001295	0.000199	0.000037
17. Construction	0.001835	0.000459	0.000054
18. Commerce	0.001945	0.000291	0.000057
19. Hotel management	0.003016	0.000254	0.000096
20. Transport and communications	0.001593	0.000625	0.000100
21. Financial intermediation	0.001644	0.000219	0.000046
22. Real estate activities, entrepreneurial services	0.001695	0.000236	0.000047
23. Public services	0.001882	0.000250	0.000052
24. Education	0.001953	0.000249	0.000054
25. Sanitary, veterinary activities, social services	0.001931	0.000252	0.000080
26. Other services, social and personal services	0.013565	0.000272	0.000127
27. Homes that employ domestic staff	0.001881	0.000229	0.000052
Labour	0.002286	0.000278	0.000064
Capital	0.002286	0.000278	0.000064
Households	0.002286	0.000278	0.000064
Total	**0.088895**	**0.010082**	**0.002603**

The sum of the columns in table 2 shows the increase in emissions for each greenhouse gas when there is a unitary injection in the exogenous demand for all accounts simultaneously. These total values, then, reflect the effects on each type of emission caused by the joint inflows to all sectors of production, factors and consumers. The pollutant most affected is CH_4, which increases by 0.088895 tons per unitary increase in all the endogenous components of the model. CO_2 emissions increase by 0.010082 kilotons and N_2O emissions increase by 0.002603 tons.

Table 2 shows which accounts have the greatest influence on greenhouse gas emissions when they receive exogenous inflows. For example, the first column shows that one unit of new exogenous demand to sector 1 (agriculture) generates 0.021919 tons of CH_4. One unit of new exogenous demand to sector 26 (other services, social activities, and personal services), on the other hand, generates 0.013565 tons of CH_4. In the second column, the energy sectors (sectors 3 and 4) and sector 11 (other non-metallic mineral products) generate 0.000726 kilotons of CO_2, 0.000663 kilotons of CO_2, and 0.002071 kilotons of CO_2, respectively. In the third column, sector 1 (agriculture) generates 0.000865 tons of N_2O to meet a new unit of exogenous demand, while sector 5 (food) generates 0.000224 tons of N_2O.

The conclusions we can draw from table 2 are that greenhouse gas emissions in Catalonia are affected very differently at the sectorial level and that the effects of production activities, factors and consumption on air pollution are very heterogeneous. Our results also show that the quantitative increases in greenhouse gas emissions will essentially depend on the account that receives the exogenous inflow in demand.

5.2. Changes in the Greenhouse Emission Multipliers

In this section we analyse the impact on emission multipliers of a 10% reduction in total greenhouse gas emissions. This percentage of reduction in emissions would bring the Catalan economy in line with the total amount of emissions allowed by the Kyoto Protocol. We considered three scenarios. First we simulated a 10% reduction in greenhouse gas emissions together with a 5% decrease in endogenous income. Then we simulated a 10% reduction in emissions with a 10% increase in endogenous income.

Finally, we simulated a 10% reduction in emissions with a 5% increase in endogenous income.

The simulation analysis involved modifying the emissions per unit of endogenous income in matrix *B*. According to expression (8), in the simulations we reduced the total emissions used to calculate matrix *B* (i.e. the *E* values) by 10%. In the three situations analysed we varied the endogenous income in the diagonal matrix $\hat{Y}$ by different amounts. In the first simulation, we decreased the values of $\hat{Y}$ by 5%. In the second and third situations we increased the values of $\hat{Y}$ by 10% and 5%, respectively.

Table 3 shows the overall impact on emission multipliers of a 10% reduction in greenhouse gas emissions and a 5% decrease in endogenous income. The last row in table 3 shows the changes in the emissions of the corresponding gas when there is an exogenous inflow to all the endogenous accounts of the model. In this situation, there is a general increase in the emissions of all greenhouse gases. CH_4 emissions increase by 12.18%, CO_2 emissions by 11.75% and N_2O emissions by 12.43%.

Table 3. Changes (%) in emission multipliers: 10% reduction in emissions and 5% reduction in endogenous income

	CH_4 (t)	CO_2 (kt)	N_2O (t)
1. Agriculture	-3.23%	13.25%	-3.65%
2. Fishing	30.29%	6.90%	24.74%
3. Energy, minerals, coke, petroleum and fuels	12.15%	-1.86%	10.35%
4. Electrical energy, gas and water	2.46%	3.45%	25.17%
5. Food	6.62%	18.53%	5.29%
6. Textile	21.93%	20.85%	20.21%
7. Manufacture of wood and cork	12.00%	19.02%	10.00%
8. Paper	28.47%	19.48%	28.69%
9. Chemistry	26.60%	9.16%	20.24%
10. Rubber and plastic products	27.94%	18.71%	27.67%
11. Other non-metallic mineral products	27.25%	-2.30%	15.07%
12. Metal	30.80%	18.37%	32.52%
13. Machinery	23.27%	23.67%	31.09%
14. Electrical equipment, electronics and optics	33.09%	22.40%	34.06%
15. Automobiles	32.29%	22.49%	33.41%
16. Other industries	28.01%	19.33%	28.91%
17. Construction	31.11%	14.19%	31.25%
18. Commerce	30.62%	22.32%	30.96%
19. Hotel management	20.30%	24.08%	19.21%
20. Transport and communications	30.86%	6.44%	12.18%
21. Financial intermediation	32.47%	26.11%	33.79%
22. Real estate activities and entrepreneurial services	31.63%	24.69%	33.34%
23. Public services	28.82%	23.23%	30.77%
24. Education	31.07%	25.61%	32.92%
25. Sanitary, veterinary activities, social services	30.07%	24.56%	19.90%
26. Other services, social and personal services	-0.41%	20.83%	9.63%
27. Homes that employ domestic staff	31.64%	27.22%	33.37%
Labour	25.06%	20.86%	26.70%
Capital	25.06%	20.86%	26.70%
Households	18.80%	14.81%	20.36%
Total	**12.18%**	**11.75%**	**12.43%**

Table 3 also shows which accounts generate the greatest increases in gas emissions when they receive an exogenous and unitary inflow. The first column shows that the highest increases in CH_4 are caused by sector 14 (electrical equipment, electronics and optics) with an increase of 33.09%, and by sector 21 (financial intermediation), with an increase of 32.47%. The highest increases in CO_2 emissions are caused by sector 27 (homes that employ domestic staff) with an increase of 27.22%, and sector 21 (financial intermediation) with an increase of 26.11%. The highest increases in N_2O emissions are caused by sector 14 (electrical equipment, electronics and optics) and sector 21 (financial intermediation), with values of 34.06% and 33.79%, respectively.

Another important aspect of table 3 is that very few sectors reduce their emission multipliers. Specifically, sector 1 (agriculture) shows a reduction in CH_4 emissions of -3.26% and sector 26 (other services, social activities, personal services) shows a reduction of -0.41%. For CO_2 emissions, sector 11 (other non-metallic mineral products) shows a reduction of -2.30% and sector 3 (energy products, minerals, coke, petroleum and fuels) shows a reduction of -1.86%. Finally, N_2O emissions, sector 1 (agriculture) shows a value of -3.65%.

Table 4. Changes (%) in emission multipliers: 10% reduction in emissions and 10% increase in endogenous income

	CH_4 (t)	CO_2 (kt)	N_2O (t)
1. Agriculture	-20.18%	-35.20%	-19.79%
2. Fishing	-49.72%	-29.74%	-44.85%
3. Energy, minerals, coke, petroleum and fuels	-33.63%	-21.97%	-31.94%
4. Electrical energy, gas and water	-25.16%	-27.14%	-44.89%
5. Food	-31.38%	-40.35%	-30.34%
6. Textile	-43.33%	-42.15%	-41.97%
7. Manufacture of wood and cork	-35.72%	-40.49%	-34.17%
8. Paper	-48.07%	-40.90%	-48.04%
9. Chemistry	-46.63%	-32.02%	-41.00%
10. Rubber and plastic products	-47.81%	-40.64%	-47.48%
11. Other non-metallic mineral products	-47.11%	-21.26%	-36.17%
12. Metal	-49.90%	-39.99%	-50.91%
13. Machinery	-44.05%	-44.59%	-49.87%
14. Electrical equipment, electronics and optics	-51.51%	-43.65%	-52.02%
15. Automobiles	-50.79%	-43.68%	-51.42%
16. Other industries	-47.91%	-41.02%	-48.53%
17. Construction	-50.14%	-37.48%	-50.06%
18. Commerce	-49.82%	-43.67%	-49.92%
19. Hotel management	-42.56%	-45.06%	-41.79%
20. Transport and communications	-49.79%	-29.47%	-33.71%
21. Financial intermediation	-51.39%	-46.64%	-52.21%
22. Real estate and entrepreneurial services	-50.64%	-45.55%	-51.76%
23. Public services	-48.58%	-44.36%	-49.91%
24. Education	-50.53%	-46.23%	-51.77%
25. Sanitary, veterinary and social services	-49.63%	-45.42%	-40.42%
26. Other services, social and personal services	-22.59%	-42.09%	-31.43%
27. Homes that employ domestic staff	-51.08%	-47.58%	-52.22%
Labour	-46.19%	-42.34%	-47.45%
Capital	-46.19%	-42.34%	-47.45%
Households	-40.81%	-36.57%	-42.19%
Total	**-34.13%**	**-34.12%**	**-34.36%**

The second scenario analysed was a 10% reduction in total greenhouse gas emissions combined with a 10% increase in production and factorial and personal income. Table 4 shows that the total changes in emission multipliers are negative for all three greenhouse gases. This means that a reduction in total emissions accompanied by an increase in production and consumer income would reduce emissions per unit of income in the regional economy. The last row in table 4 shows that there are similar reductions in greenhouse gases. Specifically, the reduction in CH_4 emission is -34.13%, the reduction in CO_2 emission is -34.12% and the reduction in N_2O emission is -34.36%.

Another aspect of table 4 that should be mentioned is that all the accounts reduce greenhouse gas emissions per unit of exogenous inflow (i. e. all the values in this table are negative). However, the quantitative impact depends on the account and the type of gas analysed. The largest reductions in greenhouse gas emission multipliers are as follows: for CH_4, sector 14 (electrical equipment, electronics and optics) -51.51%; for CO_2, sector 27 (homes that employ domestic staff) -47.58%; for N_2O, sector 27 (homes that employ domestic staff) -52.22%.

The third scenario analysed was a 10% reduction in greenhouse gas emissions together with a 5% increase in endogenous income. Table 5 shows a general reduction in multipliers, though this was not as large as in the previous scenario. Again, all values in table 5 are negative but the individual changes are different in quantitative terms. The highest value is for the effects caused by sector 21 (financial intermediation) on N_2O emissions (-35.76%). The smallest value is for the effects caused by sector 1 (agriculture) on N_2O emissions (-15.26%).

Table 5. Changes (%) in emission multipliers: 10% reduction in emissions and 5% increase in endogenous income

	CH_4 (t)	CO_2 (kt)	N_2O (t)
1. Agriculture	-15.51%	-24.85%	-15.26%
2. Fishing	-34.08%	-21.40%	-31.01%
3. Energy, minerals, coke, petroleum and fuels	-23.97%	-16.52%	-22.93%
4. Electrical energy, gas and water	-18.64%	-19.68%	-31.09%
5. Food	-22.06%	-28.00%	-21.38%
6. Textile	-29.87%	-29.18%	-28.99%
7. Manufacture of wood and cork	-24.87%	-28.14%	-23.86%
8. Paper	-33.05%	-28.40%	-33.06%
9. Chemistry	-32.10%	-22.78%	-28.57%
10. Rubber and plastic products	-32.84%	-28.16%	-32.65%
11. Other non-metallic mineral products	-32.42%	-16.13%	-25.58%
12. Metal	-34.24%	-27.81%	-34.96%
13. Machinery	-30.41%	-30.72%	-34.27%
14. Electrical equipment, electronics and optics	-35.33%	-30.10%	-35.70%
15. Manufacture of transport material	-34.87%	-30.12%	-35.33%
16. Other industries	-32.90%	-28.43%	-33.32%
17. Construction	-34.40%	-26.01%	-34.38%
18. Commerce	-34.18%	-30.09%	-34.27%
19. Hotel management	-29.27%	-30.99%	-28.75%
20. Transport and communications	-34.20%	-21.20%	-24.02%
21. Financial intermediation	-35.18%	-32.03%	-35.76%
22. Real estate and entrepreneurial services	-34.71%	-31.31%	-35.48%
23. Public services	-33.33%	-30.55%	-34.24%
24. Education	-34.57%	-31.76%	-35.43%
25. Sanitary, veterinary and social services	-34.01%	-31.23%	-28.26%
26. Other services, social and personal services	-17.04%	-29.15%	-22.59%
27. Homes that employ domestic staff	-34.91%	-32.62%	-35.70%
Labour	-31.66%	-29.26%	-32.49%
Capital	-31.66%	-29.26%	-32.49%
Households	-28.24%	-25.72%	-29.11%
Total	**-24.20%**	**-24.13%**	**-24.35%**

In summary, a reduction in greenhouse gas emissions together with a reduction in production and factorial and personal income increases emissions per unit of new income to sectors, factors and households. On the other hand, a reduction in greenhouse gas emissions together with an increase in production and personal and factorial income considerably reduces the unitary emissions of all three greenhouse gases in the regional economy.

The results of these simulations can help policymakers to understand the consequences of different modifications on economic and ecological relations. This is essential for the success of environmental policy interventions aimed at ensuring the quality of the environment and the preservation of natural ecosystems.

5.3. Decomposition of the emission multipliers matrix

Decomposing emission multipliers serves as an interesting exercise, which can show the relevance of the various interdependent channels of income in the Catalan economy and their connection with the environment.

Tables 6, 7 and 8 summarize the results of the decomposition analysis, which consists of calculating the matrices of the own net effects $B(M_1 - I)$, the open net effects $B(M_2 - I)M_1$ and, finally, the circular net effects $B(M_3 - I)M_2M_1$. Additionally, the above mentioned tables reflect the percentages that every net effect contributes to the total emission multipliers.

Analysis of table 6 reveals that the circular effects (60.25 % of the total effect) and own effects (31.09 %) have greater weight than the open effects (8.66 %).

On the other hand, in three accounts (labour, capital and households) the open effects are considerably greater than the circular effects. Nevertheless, in these accounts and account 27 (homes that employ domestic staff) there are no own effects. The reason for this is the major interrelationship between the productive sectors. It might also be consequence of the structure of the NAMEA, since it only presents an account for the consumption sector, and this can be a limitation when showing the interrelationships within the private sector of the economy.

Table 6. Additive decomposition in the emissions of CH_4 (t)

	Own Effects		Open Effects		Circular Effects		Total Effects
	Value	(%)	Value	(%)	Value	(%)	
1. Agriculture	0.001247	58.84%	0.000014	0.68%	0.000858	40.48%	0.002120
2. Fishing	0.000101	17.31%	0.000008	1.36%	0.000477	81.33%	0.000586
3. Energy, minerals, coke, petroleum and fuels	0.000153	36.67%	0.000004	1.04%	0.000260	62.29%	0.000418
4. Electrical energy, gas and water	0.000494	35.54%	0.000015	1.06%	0.000882	63.39%	0.001391
5. Food	0.005008	85.24%	0.000014	0.24%	0.000853	14.52%	0.005875
6. Textile	0.000819	47.07%	0.000015	0.87%	0.000905	52.06%	0.001739
7. Manufacture of wood and cork	0.002107	71.97%	0.000014	0.46%	0.000807	27.57%	0.002928
8. Paper	0.000354	27.01%	0.000016	1.20%	0.000941	71.78%	0.001310
9. Chemistry	0.000313	29.78%	0.000012	1.16%	0.000725	69.06%	0.001050
10. Rubber and plastic products	0.000357	28.86%	0.000015	1.17%	0.000866	69.97%	0.001238
11. Other non-metallic mineral products	0.000303	24.17%	0.000016	1.25%	0.000935	74.58%	0.001253
12. Metal	0.000173	18.86%	0.000012	1.34%	0.000733	79.80%	0.000918
13. Machinery	0.000439	38.33%	0.000012	1.02%	0.000695	60.65%	0.001146
14. Electrical equipment, electronics and optics	0.000118	15.71%	0.000010	1.39%	0.000624	82.90%	0.000753
15. Manufacture of transport material	0.000190	20.68%	0.000012	1.31%	0.000718	78.01%	0.000920
16. Other industries	0.000409	31.67%	0.000015	1.13%	0.000869	67.21%	0.001293
17. Construction	0.000330	18.01%	0.000025	1.35%	0.001479	80.63%	0.001835
18. Commerce	0.000304	15.65%	0.000027	1.39%	0.001613	82.96%	0.001944
19. Hotel management	0.001429	47.38%	0.000026	0.87%	0.001560	51.75%	0.003015
20. Transport and communications	0.000228	14.74%	0.000022	1.41%	0.001298	83.85%	0.001548
21. Financial intermediation	0.000091	5.54%	0.000026	1.56%	0.001527	92.90%	0.001644
22. Real estate and entrepreneurial services	0.000191	11.25%	0.000025	1.46%	0.001479	87.29%	0.001695
23. Public services	0.000314	16.68%	0.000026	1.37%	0.001542	81.95%	0.001881
24. Education	0.000100	5.12%	0.000031	1.57%	0.001822	93.32%	0.001952
25. Sanitary, veterinary and social services	0.000259	13.40%	0.000028	1.43%	0.001644	85.17%	0.001930
26. Other services, social and personal services	0.000737	33.30%	0.000024	1.10%	0.001452	65.60%	0.002214
27. Homes that employ domestic staff	0.000000	0.00%	0.000031	1.65%	0.001850	98.35%	0.001881
Labour	0.000000	0.00%	0.001387	60.67%	0.000899	39.33%	0.002286
Capital	0.000000	0.00%	0.001387	60.67%	0.000899	39.33%	0.002286
Households	0.000000	0.00%	0.001349	60.01%	0.000899	39.99%	0.002248
Total	**0.016570**	**31.09%**	**0.004616**	**8.66%**	**0.032111**	**60.25%**	**0.053297**

Table 7 shows the importance that every effect of interdependence has on the CO_2 emission multiplier. In this table, the circular effects have the greatest weight (42.41 % of the net total effect). The own effects (33.48 %) are in second place and the open effects (24.12 %) have least weight.

On the other hand, in both the labour and capital accounts the open effects are considerably higher than the circular effects and in the consumption account the circular effects are slightly higher than the open effects. In addition, the own effects of labour, capital and households and account 27 (homes that employ domestic staff) are void.

Table 7. Additive decomposition in the emissions of CO_2 (kt)

	Own Effects		Open Effects		Circular Effects		Total Effects
	Value	(%)	Value	(%)	Value	(%)	
1. Agriculture	0.000033	23.81%	0.000034	24.55%	0.000072	51.64%	0.000139
2. Fishing	0.000045	43.30%	0.000019	18.27%	0.000040	38.43%	0.000104
3. Energy, minerals, coke, petroleum and fuels	0.000160	83.25%	0.000010	5.40%	0.000022	11.35%	0.000192
4. Electrical energy, gas and water	0.000227	67.57%	0.000035	10.45%	0.000074	21.98%	0.000336
5. Food	0.000078	42.68%	0.000034	18.47%	0.000071	38.85%	0.000184
6. Textile	0.000056	33.41%	0.000036	21.46%	0.000076	45.13%	0.000168
7. Manufacture of wood and cork	0.000050	33.40%	0.000032	21.46%	0.000068	45.14%	0.000150
8. Paper	0.000055	32.32%	0.000037	21.81%	0.000079	45.87%	0.000172
9. Chemistry	0.000095	51.38%	0.000029	15.67%	0.000061	32.95%	0.000184
10. Rubber and plastic products	0.000074	40.91%	0.000034	19.04%	0.000073	40.05%	0.000181
11. Other non-metallic mineral products	0.000275	70.42%	0.000037	9.53%	0.000078	20.05%	0.000390
12. Metal	0.000044	32.52%	0.000029	21.74%	0.000061	45.74%	0.000134
13. Machinery	0.000030	26.02%	0.000028	23.84%	0.000058	50.14%	0.000116
14. Electrical equipment, electronics and optics	0.000041	34.64%	0.000025	21.06%	0.000052	44.30%	0.000118
15. Manufacture of transport material	0.000051	36.43%	0.000029	20.48%	0.000060	43.09%	0.000139
16. Other industries	0.000072	40.13%	0.000035	19.29%	0.000073	40.58%	0.000179
17. Construction	0.000271	59.71%	0.000059	12.98%	0.000124	27.31%	0.000454
18. Commerce	0.000083	29.48%	0.000064	22.72%	0.000135	47.80%	0.000283
19. Hotel management	0.000055	22.16%	0.000062	25.08%	0.000131	52.76%	0.000248
20. Transport and communications	0.000164	50.49%	0.000052	15.95%	0.000109	33.56%	0.000324
21. Financial intermediation	0.000027	12.67%	0.000061	28.14%	0.000128	59.19%	0.000216
22. Real estate and entrepreneurial services	0.000048	20.88%	0.000059	25.49%	0.000124	53.63%	0.000231
23. Public services	0.000051	21.10%	0.000061	25.42%	0.000129	53.48%	0.000241
24. Education	0.000018	7.36%	0.000073	29.85%	0.000153	62.79%	0.000243
25. Sanitary, veterinary and social services	0.000043	17.36%	0.000065	26.63%	0.000138	56.01%	0.000246
26. Other services, social and personal services	0.000057	24.13%	0.000058	24.45%	0.000122	51.42%	0.000236
27. Homes that employ domestic staff	0.000000	0.00%	0.000074	32.22%	0.000155	67.78%	0.000229
Labour	0.000000	0.00%	0.000168	60.67%	0.000109	39.33%	0.000278
Capital	0.000000	0.00%	0.000168	60.67%	0.000109	39.33%	0.000278
Households	0.000000	0.00%	0.000079	41.97%	0.000109	58.03%	0.000188
Total	**0.002203**	**33.48%**	**0.001587**	**24.12%**	**0.002791**	**42.41%**	**0.006580**

The information in table 8 shows the importance that every effect of interdependence has on the total emission multiplier of N_20 in every account. In this table, the circular effects present in general a few top effects that the rest of effects that we analyze (in twenty-two accounts these effects exceed 60%). The own effects and the open effects have smaller contributions to total multipliers.

Finally, in the last three accounts (labour, capital and households) the open effects are considerably higher than the circular effects. The explanation for this is the important interrelationship between the productive sectors, which means that the circular effects in these accounts are higher. Another explanation might be the structure of our social and environmental database, which has a single account for the consumption sector and, therefore, does not capture the interrelationships within the private sector of the economy.

Table 8. Additive decomposition in the emissions of N_2O (t)

	Own Effects		Open Effects		Circular Effects		Total Effects
	Value	(%)	Value	(%)	Value	(%)	
1. Agriculture	0.000048	66.38%	0.000000	0.39%	0.000024	33.23%	0.000072
2. Fishing	0.000005	25.57%	0.000000	0.86%	0.000013	73.57%	0.000018
3. Energy, minerals, coke, petroleum and fuels	0.000005	39.20%	0.000000	0.70%	0.000007	60.10%	0.000012
4. Electrical energy, gas and water	0.000008	24.26%	0.000000	0.87%	0.000025	74.87%	0.000033
5. Food	0.000199	89.19%	0.000000	0.12%	0.000024	10.69%	0.000223
6. Textile	0.000030	54.06%	0.000000	0.53%	0.000025	45.41%	0.000056
7. Manufacture of wood and cork	0.000083	78.39%	0.000000	0.25%	0.000023	21.37%	0.000106
8. Paper	0.000011	29.10%	0.000000	0.82%	0.000026	70.09%	0.000038
9. Chemistry	0.000012	36.15%	0.000000	0.74%	0.000020	63.12%	0.000032
10. Rubber and plastic products	0.000012	32.88%	0.000000	0.77%	0.000024	66.35%	0.000037
11. Other non-metallic mineral products	0.000010	27.67%	0.000000	0.83%	0.000026	71.49%	0.000037
12. Metal	0.000004	16.29%	0.000000	0.96%	0.000021	82.75%	0.000025
13. Machinery	0.000005	21.14%	0.000000	0.91%	0.000019	77.95%	0.000025
14. Electrical equipment, electronics and optics	0.000004	17.17%	0.000000	0.95%	0.000017	81.88%	0.000021
15. Manufacture of transport material	0.000006	21.59%	0.000000	0.90%	0.000020	77.51%	0.000026
16. Other industries	0.000012	32.97%	0.000000	0.77%	0.000024	66.26%	0.000037
17. Construction	0.000012	21.71%	0.000000	0.90%	0.000041	77.39%	0.000053
18. Commerce	0.000011	19.10%	0.000001	0.93%	0.000045	79.97%	0.000056
19. Hotel management	0.000052	54.04%	0.000001	0.53%	0.000044	45.43%	0.000096
20. Transport and communications	0.000018	33.31%	0.000000	0.77%	0.000036	65.92%	0.000055
21. Financial intermediation	0.000003	6.68%	0.000000	1.08%	0.000043	92.25%	0.000046
22. Real estate and entrepreneurial services	0.000005	11.15%	0.000000	1.02%	0.000041	87.83%	0.000047
23. Public services	0.000008	15.49%	0.000001	0.97%	0.000043	83.53%	0.000052
24. Education	0.000002	4.55%	0.000001	1.10%	0.000051	94.35%	0.000054
25. Sanitary, veterinary and social services	0.000009	16.51%	0.000001	0.96%	0.000046	82.53%	0.000056
26. Other services, social and personal services	0.000014	25.10%	0.000000	0.86%	0.000041	74.04%	0.000055
27. Homes that employ domestic staff	0.000000	0.00%	0.000001	1.15%	0.000052	98.85%	0.000052
Labour	0.000000	0.00%	0.000039	60.67%	0.000025	39.33%	0.000064
Capital	0.000000	0.00%	0.000039	60.67%	0.000025	39.33%	0.000064
Households	0.000000	0.00%	0.000038	60.21%	0.000025	39.79%	0.000063
Total	**0.000587**	**36.48%**	**0.000125**	**7.74%**	**0.000898**	**55.78%**	**0.001610**

6. Conclusions

In recent years, natural levels of greenhouse gases have increased due to emissions of CO_2 from fossil fuels, methane, nitrogen oxide produced by agriculture, changes in soil use, and various inert industrial gases that do not occur naturally. If the concentration of greenhouse gases continues to increase, the greenhouse effect will cause a global increase in air temperature that may lead to serious environmental problems such as climate change, damage to natural ecosystems, and impoverishment of the environment. All of these negative impacts on the environment will also have adverse effects on human health.

In this paper we have defined a linear model of emission multipliers for the Catalan economy in 2001. This model shows how unitary increases in exogenous demand affect greenhouse gas emissions. The linear SAM model is similar to the input-output model designed by Leontief, but the SAM model incorporates a greater level of endogeneity of the accounts. As a result, it captures the complete circular flow of income as it is not limited to the production sphere but incorporates income distribution and the income generation processes.

With the aim of reducing greenhouse gas emissions in the Catalan economy, we analysed three alternative scenarios. The first scenario was a 10% reduction in greenhouse gas emissions and a 5% cut in endogenous income (production, and factorial and private income). This led to an overall increase in emission multipliers of all greenhouse gases. Under this scenario, therefore, the Catalan economy would fail to comply with the objectives of the Kyoto Protocol. The second scenario was a 10% reduction in greenhouse gas emissions and a 10% increase in endogenous income. This led to a considerable reduction in the emissions of all greenhouse gases analysed. The third scenario was a 10% reduction in greenhouse gas emissions and a 5% increase in endogenous income. This scenario also led to a general reduction in greenhouse gas emissions per unit of exogenous demand. A decrease in total emissions combined with an increase in the income of the endogenous accounts would have positive effects on the environment that would enable the Catalan economy to satisfy the objectives of the Kyoto Protocol.

Additionally, we also decomposed the total emission multipliers into own effects, open effects and circular effects. This decomposition shows the different channels of income generation and its effects on greenhouse gas emissions. For all the gases considered, the circular effects are the most important component in total multipliers.

We should bear in mind that policies designed to reduce emissions may conflict with a society's development goals since there is a close relationship between economic growth, the consumption of natural resources, and the generation of pollution and environmental loads. Policymakers must, therefore, harmonise economic and ecological objectives in order to ensure both the development of society and the preservation of the environment.

Acknowledgements

This study has been supported by the Spanish Ministry of Education and Culture (Grant SEJ2007-66318).

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