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Composition of Greenhouse Gas Emissions in Spain: an Input-Output Analysis

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Abstract

Extending the traditional input-output model to account for the environmental impacts of production processes reveals the channels by which environmental burdens are transmitted throughout the economy. In particular, the environmental input-output approach is a useful technique for quantifying the changes in the levels of greenhouse emissions caused by changes in the final demand for production activities. The input-output model can also be used to determine the changes in the relative composition of greenhouse gas emissions due to exogenous inflows. In this paper we describe a method for evaluating how the exogenous changes in sectorial demand, such as changes in private consumption, public consumption, investment and exports, affect the relative contribution of the six major greenhouse gases regulated by the Kyoto Protocol to total greenhouse emissions. The empirical application is for Spain, and the economic and environmental data are for the year 2000. Our results show that there are significant differences in the effects of different sectors on the composition of greenhouse emissions. Therefore, the final impact on the relative contribution of pollutants will

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basically depend on the activity that receives the exogenous shock in final demand, because there are considerable differences in the way, and the extent to which, individual activities affect the relative composition of greenhouse gas emissions.

Keywords: Greenhouse emissions, composition of emissions, sectorial demand, exogenous shock.

1. Introduction

In recent decades, environmental pollution has received the attention of both economists and ecologists who have integrated their ideas and concepts. This integration has yielded a consistent framework that accounts for how pollution is generated and provides measures for controlling it. In an economic system, both agents and sectors process materials and energy to produce and consume goods and services. At the same time, production and consumption generate residuals that are disposed of in the environment. In other words, the residuals are the normal outcome of economic activity. The Kyoto Protocol on climate change specifies targets for emissions of greenhouse gases, which will have to be reached by the signatory countries in the period 2008-2012. The importance of this agreement makes it necessary to accurately analyse the patterns of greenhouse emissions, and also makes it necessary to define and establish the national policy measures and the environmental regulations that will reduce greenhouse emissions.

The input-output model is a framework that analyses environmental impacts by integrating both economic and technical relations that take place within the production system. It is a general tool for calculating such environmental consequences, as energy consumption, water use, land disturbance and pollution generation, caused by the activities of production. The Leontief approach, which emphasises the interdependencies among industries and sectors, is the basis for estimating the environmental effects of the changes in the elements that are external determinants of the input-output system. Although the external elements basically depend on the objective of the analysis, the conventional approach introduces all the components that make up the final demand of production activities exogenously, that is, private consumption, public consumption, investment, and exports to foreign markets.

Several recent contributions have used the input-output model to account for the greenhouse emissions and the energy embodiments of production processes. Ostblom (1998) evaluated the Swedish emissions of carbon dioxide, sulphur oxide and nitrogen oxide and analysed it taking into account the Sweden environmental goals according to the medium-term economic projections for economic growth. Lenzen (2001) constructed a generalized input-output model in which capital investment and imports were separated from final demand and internalized into intermediate demand, and presented an empirical application of the Australian energy multipliers. Lenzen (2002) decomposed the Australian environmental input-output multipliers, by using structural path analysis. This decomposition revealed the environmentally important input paths within pollution emissions, energy consumption and resource uses in the Australian production system. Recently, Lenzen et al. (2004) constructed a multi-region input-output model, which was used to calculate pollution generation, and the CO_2 multipliers for five European countries, taking into account the greenhouse gases embodied in international trade operations.

The first application for Spain was in Pajuelo (1980), which studied atmospheric pollution through an extended Leontief model that included atmospheric pollutants as a part of the production processes. Alcántara and Roca (1995) presented an input-output model to analyse the primary energy requirements and CO_2 emissions in Spain, during the period 1980-1990. More recently, Cadarso and Fernández-Bolaños (2002) calculated the total emissions in Spain during the period 1980-1995. They included private consumption emissions in the matrix of emission multipliers, and considered consumption as another category of pollutant commodities. Butnar et al. (2005) proposed a different method for analysing Spanish pollutant emissions. They calculate emissions with a generalized input-output model that determines the key sectors and the input paths of air pollution, and decomposes the global multipliers by structural path analysis. Rodríguez et al. (2005) used a multisectorial model to make an environmental and economic analysis on the basis of a social accounting matrix for Spain, with data for the year 2000. In this paper, the calculation of the generalised multipliers reveals both the environmental and the economic efficiency of Spanish production activities.

The environmental input-output approach, which has always been used to study the patterns that explain the total emissions in an economy, can also be used to analyse the relative contribution of every type of pollutant to the total amount of emissions. However, the literature on environmental input-output models contains no references to the relative composition of emissions. In this field, the use of the Leontief framework to analyse not only the total emissions but also their relative composition, in terms of types of pollutants, will provide additional knowledge to design the greenhouse abatement policies necessary if the levels of emissions specified by the Kyoto Protocol are to be reached.

The objective of this paper is to adapt the conventional Leontief model in such a way that it will be able to calculate the changes in the composition of greenhouse emissions under exogenous shocks in sectorial demand. Specifically, we provide a method that measures the relative composition of greenhouse pollution and analyses how the exogenous inflows in final demand of activities (consumption, government expenditure, investment and exports) modify the relative importance of every pollutant within the total greenhouse emissions. With this approach, therefore, we further analyse pollution generation and provide valuable information about the processes of greenhouse gases emissions. We apply this analytical context to Spain, using both economic and environmental information for the year 2000. The greenhouse emissions we consider are the six major greenhouse gases regulated by the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

This paper helps to understand the factors that underlie the generation of pollution within the production system. How changes in private consumption, public expenditure, investment, and exports affect the emission of greenhouse gases and their relative composition is an interesting question for environmental analysis. The approach we present here extends our knowledge of the economic-ecologic relationships that take place within the production sphere, and this may help to define and implement successful environmental policies.

Our results show that the emission multipliers for the six major greenhouse gases in Spain are very different in terms of quantities, and depend on such factors as the sector of activity and the type of gas analysed. The results also show different sectorial effects of exogenous shocks on the composition of emissions, depending on the activity that receives the inflow in demand. The changes in sectorial demand cause opposite effects on the relative contribution of gases, and this suggests that the impacts on the components of emissions under modifications in sectorial demand are substitutive.

The rest of the paper is organised as follows. Section 2 describes the environmental input-output model and presents the measurements of the composition of greenhouse emissions. Section 3 describes the databases used in the application to Spain and section 4 contains the empirical results. At the end of the paper we provide some concluding remarks.

2. Modeling the Composition of Greenhouse Emissions

The analytical framework that accounts for the composition of emissions is based on the input-output approach. The standard representation of the input-output model, in matrix notation, can be defined as follows:

$$X = AX + Y = (I - A)^{-1} Y \,, \qquad (1)$$

where X is the vector of final production in every sector, Y is the vector of final demand (and includes private consumption, public consumption, investment and exports to foreign markets), A is a matrix of technical coefficients (calculated by dividing the industry-by-industry direct requirements of sectorial inputs by the sectorial production) and, finally, I is the identity matrix. The multiplier analysis assumes that the technical input-ouput coefficients are constant, so matrix A does not vary. In expression (1), $(I - A)^{-1}$ is the matrix of input-output multipliers and shows the overall effects (direct and indirect) on sectorial production caused by unitary and exogenous changes in the final demand of sectors.

The input-output model can be extended to account for the environmental pollution associated with activities of production. Let B be the matrix of sectorial greenhouse emissions per unit of output, in which each element is the amount of gas type i (in physical units) per monetary unit of final production in activity j. The sectorial greenhouse emissions associated with a given level of final demand can then be calculated as follows:

$$F = B(I - A)^{-1} Y \,, \tag{2}$$

where F is the vector of i greenhouse emissions. As the different gases are measured in different units, to allow for comparisons and global estimations, we rescale matrix B to express all the emissions in common units, which are *carbon dioxide equivalents* (CO_2 eq.). This is determined by multiplying the amount of a particular gas emitted by the global warming potential of the gas (that is, its ability to absorb heat in the atmosphere). We considered that methane has a warming potential of 21 and nitrous oxide of 310. For the group of fluorocarbon gases, we used the 2002 averages: for PFC 7182, for HFC 1732 and for SF_6 23900. So, vector F will contain the total emissions of the different types of greenhouse gases measured in the common units of carbon dioxide equivalents. Following expression (2), the changes in the amount of sectorial emissions (dF) caused by exogenous changes in the final demand of activities (dY) can be calculated as:

$$dF = B(I - A)^{-1} dY. \tag{3}$$

Expression (3) captures the entire sequence between the exogenous shocks in sectorial demand and the resulting impacts on total pollutant emissions. Following the logic of the input-output model, new demand increases the sectorial production and, at the same time, increases the level of emissions. The elements in matrix $B(I - A)^{-1}$ are the *emission multipliers* that measure the amount of type i emissions caused by exogenous and unitary inflows to the final demand of sector j. Therefore, this approach makes it possible to analyse how changes in the demand of activities, for instance rises or decreases in consumption, investment and exports, affect the amount of greenhouse emissions. This is valuable information for decision-making in environmental protection, as it shows the environmental impacts associated with production activities.

The input-output model can explain the process of pollutant emissions in greater depth. In particular, this model makes it possible to analyse how changes in the final demand of activities modify the composition of greenhouse emissions, in terms of the percentages of different types of gases in total air pollution. To study the changes in the components of emissions, we can define the relative composition of greenhouse gases (vector g) by normalizing expression (2):

$$g = \frac{B(I-A)^{-1}Y}{e'B(I-A)^{-1}Y} = \frac{F}{e'F}, \tag{4}$$

where e' is a unitary row vector and g is a column vector that contains the relative contribution of every gas to total greenhouse emissions. So, g is the vector of the *relative composition of total greenhouse emissions* that is calculated by dividing the vector F of i greenhouse emissions by the total emissions ($e'F$). Notice that the only restriction for calculating vector g is that we need to know the amount of emissions by type of greenhouse gas for each sector (matrix B) in the same physical units, which are carbon dioxide equivalents.

Following expression (4), we can quantify the changes in the relative composition of emissions (dg) caused by an exogenous and unitary change in the final demand of production activities (dY) as follows:

$$dg = \frac{e'B(I-A)^{-1}YB(I-A)^{-1} - B(I-A)^{-1}Ye'B(I-A)^{-1}}{\left[e'B(I-A)^{-1}Y\right]^2}\, dY =$$

$$= \frac{B(I-A)^{-1}}{\left[e'B(I-A)^{-1}Y\right]} - \frac{B(I-A)^{-1}Ye'B(I-A)^{-1}}{\left[e'B(I-A)^{-1}Y\right]^2}\, dY =$$

$$= \frac{1}{e'B(I-A)^{-1}Y}\left[B - \frac{B(I-A)^{-1}Ye'B}{\left[e'B(I-A)^{-1}Y\right]}\right](I-A)^{-1}\, dY =$$

$$= \frac{1}{e'F}\left[B - \frac{Fe'B}{e'F}\right](I-A)^{-1}dY \ = G\,dY. \tag{5}$$

In expression (5), G is the matrix of the *changes in the relative composition of greenhouse emissions*, and has i rows of the different types of pollutants and j columns of the production activities. This matrix shows the effects of exogenous inflows in the final demand of activities on the relative contribution of the different pollutants to the amount of greenhouse emissions. The elements of this matrix can be either positive or negative (that is to say, they show a rise or a decrease, respectively, in the relative contribution of a pollutant to the total emissions). So, one individual element of this matrix, G_{ij}, determines the magnitude (positive or negative) of the change in the relative significance of pollutant i on the total emissions caused by a unitary inflow in the final demand of activity j. Notice that this way of representing the greenhouse pollution process involves a set of bilateral connections between activities and emissions and tells us how one activity influences the relative significance of the pollutants. In particular, the analytical context in expression (5) reflects the changes in the composition of greenhouse gases caused by one monetary unit of change (increase or decrease) in private consumption, public consumption, investment and exports, which are the elements considered exogenous by the input-output framework.

It should be pointed out that, irrespective of the dimension of matrix G, the sum of the columns in this matrix is zero. This can be easily checked by applying the following calculation:

$$e'G = e'\frac{1}{e'F}\left[B - \frac{Fe'B}{e'F}\right](I-A)^{-1} =$$

$$= \frac{1}{e'F}\left[e'B - \frac{e'Fe'B}{e'F}\right](I-A)^{-1} =$$

$$= \frac{1}{e'F}\left[e'B - e'B\right](I - A)^{-1} = 0.$$

This mathematical operation means that, through matrix G of changes in the composition of greenhouse gases, the context of relative emissions can be interpreted as a process of winners and losers. In other words, the modifications in the relative contribution of the components of greenhouse emissions compensate for each other.

The analytical method described above evaluates the changes in the composition of greenhouse gases under exogenous changes in sectorial demand. If the multipliers quantify the increase of emissions due to exogenous changes in sectorial demand, the relative emissions' context shows how the relative importance of each pollutant modifies due to exogenous changes in sectorial demand. The analysis of relative emissions, therefore, extends our knowledge of the effects that changes in the economic activity of production sectors may have on greenhouse emissions within the context of air pollution.

3. Databases

In this section we use the latest economic and atmospheric information for Spain, which is for the year 2000. Specifically, this information comprises the Satellite Atmospheric Emissions Account (INE, 2001) for pollution emissions, and the Supply Table and Use Table corresponding to the input-output accounts (INE, 2005) for the production system.

The Supply Matrix and the Use Matrix are given in terms of industry by product classification, following respectively the National Classification of Economic Activities (CNAE93) for activities, and the National Classification of Products (CNAP96) for products. We aggregated both matrices for as many as 17 homogeneous activities of production. Both matrices contain information expressed in basic prices.

[PLACE TABLE 1 HERE]

The direct structural coefficients or input-output coefficients matrix A is derived from the Use Matrix in two steps. First, the elements of the Use Matrix are divided by the domestic output of the absorbing industry. Second, the resulting matrix C is pre-multiplied by the transpose of the share matrix D by calculating $A = D'C$ (Miller and Blair, 1985). Matrix D is derived from the Supply Matrix and its elements are calculated by dividing each commodity by the total commodity output.

The data on atmospheric emissions are organized in matrix B, whose rows contain the amount of pollutants i generated by domestic industries j (in the columns). In our empirical application, matrix F distinguishes the six major greenhouse gases regulated by the Kyoto Protocol. Like the input-output coefficients matrix, the columns in B contain 17 different activities of production. The original units of emissions have been rescaled so that they are all expressed in the same units, which are carbon dioxide equivalents (CO_2 eq.). We show both the production sectors and the greenhouse gases in table 1.

4. Empirical Application to the Spanish Greenhouse Emissions

The analytical context discussed in section 2 shows how exogenous and unitary inflows to final demand of production activities affect the relative composition of greenhouse emissions. Specifically, by calculating matrix G we provide a general representation of the ecologic-economic channels taking place in the production system. This tells us how the shocks in sectorial production, as changes in consumption, investment and exports, modify the relative importance of every greenhouse gas within total air pollution.

The information reported by the model show different aspects of greenhouse emissions. First, we focus on the emission multipliers that quantify the changes in the levels of emissions under changes in final demand. Second, we show the context of relative composition of greenhouse emissions. Finally, we analyse the patterns that explain the changes in the relative contribution of pollutants within the total emissions.

4.1. Emission Multipliers

Following the logic behind the input-output representation of pollution processes, an exogenous increase in the final demand of activities will lead to an increase in sectorial production to cover the new demand and, as the levels of pollution have a direct and fixed relationship with the levels of production, this will also lead to an increase in the levels of emissions.

In this section, we quantify the changes in the amount of greenhouse gas emissions when there are exogenous and unitary changes in the final demand of activities. From this perspective, we can identify which production activities are responsible for the greatest increases in the levels of pollution after an increase in their exogenous demand. These results are very valuable for designing abatement measures of industrial pollution.

Table 2 contains the elements of matrix $B(I - A)^{-1}$ corresponding to the emission multipliers. The elements in this table show the changes in the Spanish emissions when there is an exogenous and unitary inflow to the activities of production. Specifically, table 2 should be read as follows. The element of the first row and first column indicates that when agriculture (sector 1) receives an exogenous and unitary increase in its final demand, CH_4 emissions will increase by 586.23 tonnes of CO_2 eq.

The sum of the columns in table 2 shows the increase in the levels of greenhouse emissions when the activity corresponding to the column receives a unitary and exogenous injection in demand. Likewise, these total values quantify the effects of pollution, in terms of carbon dioxide equivalents, generated by the exogenous inflows to each activity. As we can see from table 2, the greatest column sum corresponds to energy (sector 2), which generates 2584.01 tonnes of CO_2 eq. per exogenous and unitary inflow received. This effect is followed by minerals (sector 4), which generates 2232.91 tonnes of CO_2 eq. and agriculture (sector 1) with 1654.33 tonnes of CO_2 eq. These three activities show considerable ability to generate greenhouse emissions in Spain, and jointly amount to about 52% of the total emissions reflected in table 2.

On the other hand, new demand in metals (sector 3) and automobiles (sector 7) causes the smallest increases in emissions (170.58 and 188.54 tonnes of CO_2 eq., respectively). It is interesting to point out that most service activities (from sector 13 to sector 17) have less impact on the levels of emissions. The exception is transportation (sector 14) which, with 612.91 tonnes of CO_2 eq., generates 5% of the total emission multipliers.

[PLACE TABLE 2 HERE]

The sum of rows in table 2 shows the increase in the emissions of the pollutant gas in the row when there is one unitary injection in the final demand of all the activities simultaneously. These total values reflect, therefore, the pollution effects on every type of emission caused by the joint inflows to all the sectors of production. From this table, the greatest effect is on CO_2 emissions, which is quantified as 10315.42 tonnes of CO_2 eq. (82.8% of the total). This is followed by the effect on CH_4 emissions, which is quantified as 1126.53 tonnes of CO_2 eq. (9.05% of the total). Therefore, these two gases together make up about 92% of Spanish emission multipliers. On the other hand, the

SF_6 and PFC multipliers show the smallest values, which amount 3.83 and 8.00 tonnes of CO_2 eq., respectively.

Another important aspect that table 2 makes clear is that some bilateral effects are very significant in terms of pollution generation, and this means that some activities have a strong influence on Spanish greenhouse emissions. For example, an inflow to energy (sector 2) generates 2508.46 tonnes CO_2 eq. of CO_2, which amount 20% of the total emission multipliers. Additionally, an inflow to minerals (sector 4) generates 2167.68 tonnes CO_2 eq. of CO_2 (17.41% of the total effects), and an inflow to agriculture (sector 1) generates 586.23 tonnes CO_2 eq. of CH_4 (4.7% of the total effects). These results suggest that the inflows received by a small number of activities concentrate most of the pollution generation in the Spanish production system. This concentration of total emissions in just a few sectors of production may make it easier to apply the policy measures aimed at reducing the levels of industrial greenhouse pollution.

To sum up, table 2 indicates that Spanish emissions have important asymmetries at the sectorial level, and the effects of production activities on air pollution are very heterogeneous. Our results show that the increase in the greenhouse emissions caused by the Spanish production system will essentially depend on the activity that receives the exogenous inflow in final demand. The results also show that there are considerable differences in the quantitative significance of the different gases analysed.

4.2. Composition of Greenhouse Emissions

This section presents the empirical results of the relative greenhouse emissions. Table 3 contains the composition of sectorial emissions, that have been calculated by dividing the emission multipliers' matrix ($B(I - A)^{-1}$) with respect the transposed matrix of the total emission multipliers in each activity, that is, the transposed matrix of the column sum in the emission multipliers' matrix (e' $B(I - A)^{-1})^T$. The elements in table 3 show, therefore, the relative contribution of each pollutant to the total emissions of each activity of production.

[PLACE TABLE 3 HERE]

The relative significance of gases is very different, and depends basically on the sector and the type of gas analysed. The higher CH_4 relative emissions are in agriculture (sector 1), and in public services (sector 17), representing 35.44% and 36.80% of the total emissions of agriculture and public services respectively. For CO_2 emissions, the higher relative significance is in energy (sector 2), metals (sector 3) and minerals (sector 4), being 97.08%, 97.33% and 97.08%, respectively. For N_2O emissions, the higher values are in agriculture (sector 1) and food (sector 8), amounting 26.74% and 18.37%, respectively. On the other hand, table 3 shows that in all the activities the relative importance of SF_6, HFC and PFC is very small in comparison with the other pollutants. To sum up, table 3 shows that agriculture (sector 1) and food (sector 8) have relative high emissions of CH_4 and N_2O, while energy (sector 2), metals (sector 3) and minerals (sector 4) have relatively high emissions for CO_2. Also from table 3, chemistry (sector 5) has relatively high emissions of HFC and machinery (sector 6) has relatively high emissions of PFC and SF_6.

[PLACE TABLE 4 HERE]

Table 4 shows the relative contribution of every gas with respect to the total greenhouse emissions in Spain. This information corresponds to vector *g* that has been defined in expression (4) above. From this table, CO_2 is the most important component in the Spanish emissions, amounting to 82.21% of the greenhouse pollution. This is followed by the relative contribution of CH_4, which is 10.01% of the emissions in the year 2000.

On the other hand, the SF_6 emissions and the PFC emissions contributed little to Spanish emissions and together made up 0.17% of greenhouse pollution.

4.3. Changes in the Composition of Greenhouse Emissions

This section shows the changes in the relative composition of pollutants within the amount of greenhouse emissions. Specifically, table 5 constitutes a modification of the original context of changes in relative emissions, as it contains the non-normalized elements corresponding to the matrix $(e'F)G$. So, the values in table 5 show the amount of reassigned tonnes of CO_2 eq. among pollutants when the total emissions are held constant at the initial level. In other words, it shows the tonnes of emissions changing from one gas type to another because of the changes in their relative contribution. For example, the first element in table 5 shows that when agriculture (sector 1) receives an exogenous inflow, the relative CH_4 emissions increase by 420.62 tonnes of CO_2 eq. On the other hand, the same inflow to agriculture reduces the relative CO_2 emissions by 736.24 tonnes of CO_2 eq. Notice that the columns in this table add up to zero as do those in matrix G, and this means that we can also interpret this table as a process of winners and losers in which the effects on the gases compensate for each other.

Reading down the columns in table 5 shows how much pollution is reassigned among the types of pollutants under an exogenous and unitary increase in the demand of the sector in the column. Of the different activities, agriculture (sector 1), energy (sector 2) and minerals (sector 4) have the largest column values and this means that these activities are more able to modify the relative importance of pollutants under exogenous changes in their demand. On the other hand, automobiles (sector 7), textiles (sector 9) and some services, such as commerce (sector 13) and finance (sector 15), are not so able to modify the relative emissions.

Reading across the rows in table 5 shows the changes in the relative emissions of the gas in the row when there is an exogenous and unitary increase in the final demand of all the activities simultaneously. As we can see, CH_4 emissions show the largest adjustment: its relative emissions are reduced by 119.80 tonnes of CO_2 eq. when all the activities raise their demand by one monetary unit. The row sums of SF_6 and PFC are the smallest, and their relative emissions are reduced by 2.94 and 6.15 tonnes of CO_2 eq., respectively.

It should be pointed out that, while the relative emissions of CO_2 and N_2O increase under a new and exogenous demand to all the activities of production, the relative emissions of CH_4 decrease. Furthermore, if we compare the row sum for CO_2 and N_2O in table 5 with those of the other gases, we can conclude that these two pollutants have substitutive effects with respect to the other greenhouse gases under exogenous inflows to the productive system.

[PLACE TABLE 5 HERE]

Table 5 also shows that the changes in the relative greenhouse emissions have no direct relation with the relative distribution in activities (table 3). Moreover, if we compare tables 2 and 5, we can see how important it is to understand the pollution generation process and its relation with production activities. Our results show that the changes in the emissions levels (table 2) are very different from the changes in the relative emissions (table 5). In fact, while the largest adjustment to the levels of Spanish pollution was in CO_2 emissions, the largest adjustment to Spanish relative emissions was in CH_4 emissions.

In summary, the analysis of changes in the relative emissions completes our knowledge of the greenhouse gas emissions and clarifies the underlying effects that generate environmental consequences within the production system. This information is very important for a successful environmental policy aimed at getting improvements in the environmental efficiency of an economy.

5. Conclusions

This paper has analysed the relative composition of greenhouse gas emissions in Spain, through the use of both economic and atmospheric emissions data for the year 2000. Specifically, we have extended the traditional environmental input-output model to account for the relative composition of total emissions and its modifications under changes in the exogenous components of the input-output approach. This provides additional information about the complex process of pollution generation and how it is related to production activities. In particular, the extension of the environmental input-output model has revealed that the modifications in the relative status of the six major greenhouse gases regulated by the Kyoto Protocol are a set of bilateral connections, which tell us how the inflows to activities affect the relative contribution of every pollutant within the amount of emissions.

Our application to Spanish emissions reveals important asymmetries in the effects of sectors on the levels of greenhouse pollution. One important finding is, therefore, that there are significant differences in the way some activities affect greenhouse emissions. This suggests that even if the pollution abatement policies in the production sphere focus on only a few activities the effects on the environment could be extremely beneficial. Our results also show that very few activities have a considerable influence on the process of relative emissions.

In the context of environmental preservation and pollution control, the underlying effects that contribute to the processes of environmental burdens and pollution generation must be understood. To explain the environmental consequences of the productive system, we require flexible analyses that capture both economic and ecologic relationships taking place within pollution generation processes. The analytical context we present in this paper identifies several aspects that can clarify the generation and the transmission of environmental impacts.

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Table 1. Sectors of Production and Greenhouse Gases

j	**Sectors**	*i*	**Gases**
1	Agriculture	1	Methane (CH_4)
2	Energy	2	Carbon Dioxide (CO_2)
3	Metals	3	Nitrous Oxide (N_2O)
4	Minerals	4	Sulphur Hexafluoride (SF_6)
5	Chemistry	5	Hydrofluorocarbons (HFC)
6	Machinery	6	Perfluorocarbons (PFC)
7	Automobiles		
8	Food		
9	Textiles		
10	Paper		
11	Other Industry		
12	Construction		
13	Commerce		
14	Transportation		
15	Finance		
16	Private Services		
17	Public Services		

Table 2. Emission Multipliers ($B(I-A)^{-1}$). Tons of Carbon Dioxide Equivalents

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Total**
CH_4	586.23	41.64	1.42	9.72	13.16	5.46	4.48	200.81	20.30	35.59	19.78	9.70	29.14	8.05	6.69	9.06	125.30	1126.53
CO_2	623.83	2508.46	166.03	2167.68	574.19	336.59	174.53	478.88	262.13	526.52	292.99	499.86	228.28	591.68	236.75	456.66	190.37	10315.42
N_2O	442.37	33.21	2.59	53.19	70.79	10.11	7.37	153.37	22.59	22.62	24.81	17.46	24.61	12.21	7.52	15.72	23,41	943.96
SF_6	0.09	0.06	0.06	0.20	0.11	1.99	0.34	0.09	0.07	0.08	0.18	0.29	0.05	0.06	0.05	0.05	0.06	3.83
HFC	1.62	0.52	0.35	1.70	23.46	1.05	1.09	1.61	2.11	1.69	3.00	1.39	1.02	0.78	1.55	7.66	1.24	51.84
PFC	0.18	0.12	0.13	0.42	0.23	4.15	0.72	0.19	0.14	0.18	0.37	0.60	0.10	0.13	0.10	0.11	0.13	8.00
Total	1654.33	2584.01	170.58	2232.91	681.94	359.34	188.54	834.95	307.34	586.69	341.13	529.29	283.20	612.91	252.65	489.27	340.50	12449.57

Table 3. Composition of Sectorial Emissions in Spain $\left(\frac{B(I-A)^{-1}}{\left[e'B(I-A)^{-1}\right]^{T}}\right)$

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
CH_4	35.44%	1.61%	0.83%	0.44%	1.93%	1.52%	2.38%	24.05%	6.60%	6.07%	5.80%	1.83%	10.29%	1.31%	2.65%	1.85%	36.80%
CO_2	37.71%	97.08%	97.33%	97.08%	84.20%	93.67%	92.57%	57.35%	85.29%	89.74%	85.89%	94.44%	80.61%	96.54%	93.71%	93.34%	55.91%
N_2O	26.74%	1.29%	1.52%	2.38%	10.38%	2.81%	3.91%	18.37%	7.35%	3.86%	7.27%	3.30%	8.69%	1.99%	2.98%	3.21%	6.87%
SF_6	0.01%	0.00%	0.04%	0.01%	0.02%	0.55%	0.18%	0.01%	0.02%	0.01%	0.05%	0.05%	0.02%	0.01%	0.02%	0.01%	0.02%
HFC	0.10%	0.02%	0.20%	0.08%	3.44%	0.29%	0.58%	0.19%	0.69%	0.29%	0.88%	0.26%	0.36%	0.13%	0.61%	1.57%	0.36%
PFC	0.01%	0.00%	0.08%	0.02%	0.03%	1.16%	0.38%	0.02%	0.04%	0.03%	0.11%	0.11%	0.04%	0.02%	0.04%	0.02%	0.04%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 4. Composition of Total Greenhouse Emissions in Spain (*g*)

Gases	g_i
Methane (CH_4)	10.01%
Carbon Dioxide (CO_2)	82.21%
Nitrous Oxide (N_2O)	7.03%
Sulphur Hexafluoride (SF_6)	0.05%
Hydrofluorocarbons (HFC)	0.58%
Perfluorocarbons (PFC)	0.12%
Total	**100.00%**

Table 5. Changes in Relative Greenhouse Emissions (*e'FG*). Tons of Carbon Dioxide Equivalents

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
CH_4	420.62	-217.05	-15.65	-213.82	-55.11	-30.52	-14.39	117.22	-10.47	-23.14	-14.37	-43.28	0.79	-53.31	-18.61	-39.92	91.22	-119.80
CO_2	-736.24	384.07	25.79	331.94	13.55	41.16	19.52	-207.55	9.46	44.18	12.54	64.71	-4.54	87.79	29.04	54.42	-89.57	80.29
N_2O	326.02	-148.54	-9.41	-103.86	22.83	-15.16	-5.89	94.64	0.98	-18.64	0.82	-19.77	4.69	-30.90	-10.25	-18.69	-0.54	68.33
SF_6	-0.81	-1.35	-0.03	-1.01	-0.26	1.80	0.24	-0.36	-0.10	-0.23	-0.01	0.00	-0.11	-0.27	-0.09	-0.22	-0.12	-2.94
HFC	-7.89	-14.33	-0.63	-11.14	19.54	-1.02	0.01	-3.19	0.35	-1.68	1.04	-1.66	-0.61	-2.74	0.10	4.85	-0.72	-19.74
PFC	-1.70	-2.81	-0.07	-2.12	-0.55	3.74	0.50	-0.76	-0.21	-0.49	-0.02	0.00	-0.22	-0.57	-0.19	-0.45	-0.26	-6.15
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00