

Working papers series

WP ECON 10.14

“Seeking a decomposition of CO₂ production emissions in the Andalusian economy”

M. Alejandro Cardenete (Universidad Pablo de Olavide)

Patricia Fuentes-Saguar (Universidad Pablo de Olavide)

Clemente Polo (Universidad Autónoma de Barcelona)

JEL Classification numbers: C67, D58, Q43, Q51, R13.

Keywords: Social Accounting Matrices, Regional Accounts, Input-Output Tables, Energy SAM Multipliers, CO₂ emissions.



Department of Economics

A decomposition of CO₂ production emissions in the Andalusian economy

M. Alejandro Cardenete
Patricia D. Fuentes Saguar
University Pablo de Olavide

Clemente Polo
University Aut3noma de Barcelona

Summary

The aim of this paper is to analyze the energy sector in Andalusia, a Spanish region, and its importance from the viewpoint of final energy consumption, trying to determine which demands are the most costly to satisfy in terms of emissions of pollutants to the atmosphere. To do this, we apply an additive multiplier decomposition methodology to the Andalusian Social Accounting Matrix for the year 1995. The method implemented allow us disaggregate the Andalusian energy sector's revenue-generating process into different effects depending on the source of the demand. To gain a better understanding of the behaviours of the different branches of the economy, we divide Andalusian productive activities into two groups, which we call subsystems (energy subsystem and complementary subsystem). We then apply the multiplier decomposition methodology to each one separately. This way, we can identify the influence that the final demand of each of these groups has on income generation and energy sector emissions in the Andalusian economy. The information obtained from this exercise allow know which sectors are the final main responsible of the emissions, and confirm that Construction and some branches of the services sector are the most costly in terms of CO₂ emissions.

Keywords: Social Accounting Matrices, Regional Accounts, Input-Output Tables, Energy SAM

Multipliers, CO₂ emissions.

JEL Codes: C67, D58, Q43, Q51, R13.

M.A. Cardenete thanks research grants MICINN-ECO2009-11857 and SGR2009-578. P. Fuentes Thanks grant SEJ-479. C. Polo thanks the Spanish Ministry of Education by its financial support, grant SEJ2007-61046. As usual, the authors are responsible for all opinions and errors.

1. Introduction

The main objective of this article is to provide a breakdown of total emissions for the energy and non-energy subsystems of the Andalusian economy. In particular, the so called own, internal, feedback, spillover and scale effects are defined and calculated. As shown by Cardenete, Fuentes-Saguar and Polo (2010) and Manresa and Sancho (2007), some energy sectors make an intensive use of energy and are responsible for a good share of CO₂ emissions. However, the emissions caused in the production of energy are to a large extent caused by the demand of non-energy sectors. This article attempts to clarify the effects of those interrelations on emissions.

The starting point is a standard decomposition of sectoral gross production or income for the energy and non-energy subsystems of the Andalusian economy. Total income accruing to energy and non-energy accounts from an exogenous income injection directed to endogenous energy (non-energy) accounts can be decomposed into the intermediate incomes in energy (non-energy) and non-energy (energy) transactions and the injection. Furthermore, the intermediate production of the energy (non-energy) can be broken down into the so called own, internal and feedback effect (Alcántara and Padilla, 2009).

The calculations presented in this article are based in the Social Accounting Matrices (SAM) multipliers analysis. The beginnings of the analysis with Social Accounting Matrices are found in Stone (1962) and in Pyatt & Round (1979) among others, having its first applications in Spain in works such as Kehoe, Manresa, Polo & Sancho (1988). Regarding specific studies about energy in Spanish economy there is, among others, the one by Alcántara & Roca (1995) and another by Alcántara & Padilla (2009) which uses Input-Output Analysis to measure energy demands and

CO₂ emissions on a national scope. A study focusing on a regional scope is Manresa & Sancho (2004) where SAM analysis is used to estimate energy intensities and CO₂ emissions in Catalonia.

The data base used to calibrate the coefficients of the model is the Andalusian SAM (SAMAND-95) elaborated by Cardenete and Moniche (2001) for 1995. CO₂ coefficient emissions per value unit are taken from Cardenete, Fuentes-Saguar and Polo (2010).

The body of this paper is divided into five sections, the first one of which is the present introduction. The second and the third section present a brief description of the production model and its extension to emissions. In the fourth section is presented the application and we displays the results obtained. Following these results, in the fifth section we state the conclusions and discuss the constraints and possible extensions of the model.

2. Energy and non-energy subsystems in a SAM framework

For convenience, it will be used the same notation employed by Cardenete, Fuentes-Saguar, and Polo (2010). Let $Y = (Y_{ij})$ be the $N \times N$ matrix of income flows among the N accounts in the SAM economy and $M \subset N$ be the set of endogenous accounts. Once defined the expenditure coefficients

$$a_{ij} \equiv \frac{Y_{ij}}{\sum_{i=1}^N Y_{ij}} = \frac{Y_{ij}}{Y_j}, i, j = 1, 2, \dots, N \quad (1)$$

total income accruing to account $i \in M$ can be subdivided into the income received from all endogenous and exogenous accounts

$$Y_i = \sum_{j=1}^M a_{ij} Y_j + \sum_{j=M+1}^N a_{ij} Y_j, i = 1, 2, \dots, M \quad (2)$$

or using matrix notation as

$$y_m = A_{mm} y_m + A_{mn} y_n \quad (3)$$

where

$$A_{mm} = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1M} \\ a_{21} & a_{21} & \dots & a_{2M} \\ & & \dots & \\ a_{M1} & a_{M2} & \dots & a_{MM} \end{pmatrix}, A_{mn} = \begin{pmatrix} a_{1M+1} & a_{1M+2} & \dots & a_{1N} \\ a_{2M+1} & a_{2M+2} & \dots & a_{2N} \\ & & \dots & \\ a_{MM+1} & a_{MM+2} & \dots & a_{MN} \end{pmatrix}.$$

The solution of (3) provides the income vector of endogenous accounts

$$y_m = (I - A_{mm})^{-1} A_{mn} y_n = B_{mm} A_{mn} y_n = B_{mm} d_m \quad (4)$$

where $B_{mm} = (I - A_{mm})^{-1}$ is the square generalized multiplier matrix and d_m the vector $A_{mn} y_n$ of exogenous income directed to the endogenous accounts. Notice that the vector d_m depends on the partition between endogenous and exogenous accounts. From the point of view of emissions, it is sensible to partition M into energy $E = \{1, 2, \dots, E\}$ and non-energy accounts $R = \{E + 1, E + 2, \dots, P, P + 1, \dots, M\}$ that include non-energy production sectors and other endogenous accounts. Then, equation (3) can be rewritten as

$$\begin{pmatrix} y_e \\ y_r \end{pmatrix} = \begin{pmatrix} B_{ee} & B_{er} \\ B_{re} & B_{rr} \end{pmatrix} \begin{pmatrix} d_e \\ d_r \end{pmatrix} \quad (5)$$

For this partition of the endogenous accounts, the matrix A_{mm} in (3) and substituting (5) into (3)

$$\begin{pmatrix} y_e \\ y_r \end{pmatrix} = \begin{pmatrix} A_{ee} & A_{er} \\ A_{re} & A_{rr} \end{pmatrix} \begin{pmatrix} y_e \\ y_r \end{pmatrix} + \begin{pmatrix} d_e \\ d_r \end{pmatrix} \quad (6)$$

Substituting (5) into (6) one obtains the vector of gross productions required to satisfy an exogenous vector of final demand.

$$\begin{pmatrix} y_e \\ y_r \end{pmatrix} = \begin{pmatrix} A_{ee} & A_{er} \\ A_{re} & A_{rr} \end{pmatrix} \begin{pmatrix} B_{ee} & B_{er} \\ B_{re} & B_{rr} \end{pmatrix} \begin{pmatrix} d_e \\ d_r \end{pmatrix} + \begin{pmatrix} d_e \\ d_r \end{pmatrix} \quad (7)$$

The matrix of expenditure coefficients can be additively decomposed into two matrices:

$$\begin{pmatrix} A_{ee} & A_{er} \\ A_{re} & A_{rr} \end{pmatrix} = \begin{pmatrix} \hat{A}_{ee} & 0 \\ 0 & \hat{A}_{rr} \end{pmatrix} + \begin{pmatrix} A_{ee}^- & A_{er} \\ A_{re} & A_{rr}^- \end{pmatrix} \quad (8)$$

Where \hat{A}_{ee} and \hat{A}_{rr} are diagonal matrices where positive entrances are the diagonal elements in the matrices A_{ee} and A_{rr} , respectively and $A_{ee}^- = A_{ee} - \hat{A}_{ee}$ and $A_{rr}^- = A_{rr} - \hat{A}_{rr}$. Substituting (8) into (7)

$$\begin{pmatrix} y_e \\ y_r \end{pmatrix} = \left[\begin{pmatrix} \hat{A}_{ee} & 0 \\ 0 & \hat{A}_{rr} \end{pmatrix} + \begin{pmatrix} A_{ee}^- & A_{er} \\ A_{re} & A_{rr}^- \end{pmatrix} \right] \begin{pmatrix} B_{ee} & B_{er} \\ B_{re} & B_{rr} \end{pmatrix} \begin{pmatrix} d_e \\ d_r \end{pmatrix} + \begin{pmatrix} d_e \\ d_r \end{pmatrix} \quad (9)$$

The system of equations (9) determines the income levels of the energy and non-energy subsystem given the exogenous income directed to them for a given partition of the accounts among endogenous and exogenous. The solution for the energy and non-energy accounts

$$\begin{aligned} y_e &= \hat{A}_{ee} B_{ee} d_e + \hat{A}_{ee} B_{er} d_r + (A_{ee}^- B_{ee} + A_{er} B_{re}) d_e + (A_{ee}^- B_{er} + A_{er} B_{rr}) d_r + d_e \\ y_r &= \hat{A}_{rr} B_{re} d_e + \hat{A}_{rr} B_{rr} d_r + (A_{re} B_{ee} + A_{rr}^- B_{re}) d_e + (A_{re} B_{er} + A_{rr}^- B_{rr}) d_r + d_r \end{aligned} \quad (10)$$

Setting alternatively d_r and d_e equal to zero, the income levels of energy and non-energy accounts are obtained when exogenous income is directed only to the energy and non-energy sectors, respectively. For $d_r = 0$

$$\begin{aligned} y_e / dr=0 &= (\hat{A}_{ee} B_{ee} + A_{ee}^- B_{ee} + A_{er} B_{re}) d_e + d_e \\ y_r / dr=0 &= (\hat{A}_{rr} B_{re} + A_{re} B_{ee} + A_{rr}^- B_{re}) d_e \end{aligned} \quad (11)$$

and for $d_e = 0$

$$\begin{aligned} y_e / de=0 &= (\hat{A}_{ee} B_{er} + A_{ee}^- B_{er} + A_{er} B_{rr}) d_r \\ y_r / de=0 &= (\hat{A}_{rr} B_{rr} + A_{re} B_{er} + A_{rr}^- B_{rr}) d_r + d_r \end{aligned} \quad (12)$$

Obviously,

$$y = \begin{pmatrix} y_e \\ y_r \end{pmatrix} = \begin{pmatrix} y_e / dr=0 + y_e / de=0 \\ y_r / dr=0 + y_r / de=0 \end{pmatrix} \quad (13)$$

There are four terms in the first equation in (11)¹. The first named the own effect (OE)

$$y_e^{OE} / dr=0 = \hat{A}_{ee} B_{ee} d_e \quad (14)$$

indicates the production of each energy commodity required to satisfy the final demand of that commodity ignoring that to produce it other energy and non-energy commodities have to be produced and that in turn requires to produce the energy commodity. Those effects known as the internal effect (IE) and feedback effect (FE) are captured by the next two expressions in the equation:

$$\begin{aligned} y_e^{IE} / dr=0 &= A_{ee}^- B_{ee} d_e \\ y_e^{FE} / dr=0 &= A_{er} B_{re} d_e \end{aligned} \quad (15)$$

The last term is just the exogenous injection also called scale effect (SE):

$$y_e^{SE} / dr=0 = d_e \quad (16)$$

Finally, the second equation in (11)

$$y_r^{SPE} / dr=0 = (\hat{A}_{rr} B_{re} + A_{re} B_{ee} + A_{rr}^- B_{re}) d_e \quad (17)$$

indicates the production of non-energy sectors required to satisfy the final demand directed to the energy subsystem and is named spillover effect (SPE). If the vector d_e is substituted in the previous expressions by a diagonal matrix \hat{D}_e that includes in the diagonal the elements of the vector d_e , the requirements are broken down by the energy type and energy sector that receives the injection.

3. CO2 emissions in production

For the five energy commodities in the SAMAND-95, Cardenete, Fuentes-Saguar and Polo (2010) calculated two $E \times 1$ row emission coefficients vectors, c_{el}^T and c_{eF}^T expressed in value units for intermediate and final uses². They also calculate production emissions applying the intermediate emission coefficient vector to the matrix of energy requirements

$$E_I = c_{el}^T A_{ep} y_p = c_{el}^T \begin{pmatrix} A_{ee} & A_{ep-e} \end{pmatrix} \begin{pmatrix} y_e \\ y_{p-e} \end{pmatrix} \quad (18)$$

where c_{el}^T is the $E \times 1$ row vector of intermediate emissions coefficients, A_{ep} is the $E \times P$ submatrix of expenditure coefficients defined for energy commodities in all production activities and y_p is the income vector of production sectors. (18) can also be expressed in terms of a sectoral emissions coefficients c_p

$$E_I = c_p^T y_p = \begin{pmatrix} c_e^T & c_{p-e}^T \end{pmatrix} \begin{pmatrix} y_e \\ y_{p-e} \end{pmatrix} \quad (19)$$

where $c_p^T = \begin{pmatrix} c_e^T & c_{p-e}^T \end{pmatrix} = c_{el}^T \begin{pmatrix} A_{ee} & A_{ep-e} \end{pmatrix}$. In a similar fashion, emissions by non-productive endogenous accounts can be calculated

$$E_F = c_{eF}^T A_{em-p} y_{m-p} = c_{m-p}^T y_{m-p} \quad (20)$$

where $c_{m-p}^T = c_{eF}^T A_{em-p}$.

Finally, let it denote by $c_m^T = (c_e^T \quad c_{p-e}^T \quad c_{m-p}^T)$ the $M \times 1$ emissions vector for productive and non-productive endogenous accounts. Then, total emissions

$$E_T = c_m^T y_m = c_p^T (A_{mm} y_m + d_m) = c_m^T (A_{mm} B_{mm} d_m + d_m) \quad (21)$$

The decomposition explained in the previous section can now be applied to the partition of the production sectors into the energy and non-energy subsystems to breakdown total emissions (total effect) into the own, internal, feedback, spillover and scale effects. Table 1 indicates the breakdown of emissions for the two subsystems.

Table 1		
Emissions breakdown	Energy subsystem	Non-energy subsystem
Own effect	$Ey_e^{OE} / dr=0 = c_e^T \hat{A}_{ee} B_{ee} d_e$	$Ey_r^{IE} / de=0 = c_r^T \hat{A}_{rr} B_{rr} d_r$
Internal effect	$Ey_e^{IE} / dr=0 = c_e^T A_{ee}^- B_{ee} d_e$	$Ey_r^{IE} / de=0 = c_r^T A_{rr}^- B_{rr} d_r$
Feedback effect	$Ey_e^{FE} / dr=0 = c_e^T A_{er} B_{re} d_e$	$Ey_e^{FE} / de=0 = c_r^T A_{re} B_{re} d_r$
Scale effect	$Ey_r^{SE} / dr=0 = c_e^T d_e$	$Ey_r^{SE} / de=0 = c_r^T d_r$
Spillover effect	$Ey_r^{SPE} / dr=0 = c_r^T (\hat{A}_{rr} B_{re} + A_{re} B_{ee} + A_{rr}^- B_{re}) d_e$	$Ey_e^{RE} / de=0 = c_e^T (\hat{A}_{ee} B_{er} + A_{ee}^- B_{er} + A_{er} B_{rr}) d_r$

The emissions of the spillover effect of the non-energy subsystem

$$E y_e^{RE} /_{de=0} = c_e^T (\hat{A}_{ee} B_{er} + A_{ee}^- B_{er} + A_{er} B_{rr}) d_r = c_e^T (A_{ee} B_{er} + A_{er} B_{rr}) d_r \quad (22)$$

it indicate the emissions of the energy subsystem that can be attributed to the satisfaction of the exogenous injection of the non-energy subsystem.

4. Breakdown of CO₂ emissions in the energy and non-energy subsystems

Cardenete, Fuentes and Polo (2010) use a SAM model to estimate sectoral energy intensities and total emissions of the Andalusian economy. The model is specified with a SAM elaborated by Cardenete and Moniche (2001). For the emission calculations, the subset of endogenous accounts includes all production (energy and non-energy) activities and the household sector. Out of 44,056.0 kilotons (kt.) of total emissions, 40,847.4 kt. were generated by the production activities (sectoral emissions) and 3,208.7 kt. by domestic final demand. These figures are reasonably close to those published by different organisms of the regional Government.³ At any rate, the results indicate that production activities generate 90 percent of the emissions, and final domestic demand⁴ remaining 10 percent. This may come as a surprise since final consumption demand of energy amounts to 27 percent of all energy consumed in value terms. This apparent paradox is explained by the existence of important price differentials between final and intermediate uses and the fact that exports of refined oil are excluded in the calculations of final emissions.

In this paper we explore which final demands are the latest responsible for the CO₂ emissions generated in the production process. The energy sector is in Andalusia, as in Spain, which generates higher carbon emissions in its productive

activity. However, this energy (which generates these emissions) is produced to satisfy energy and non-energy final demands. Therefore, this analysis completed the usual information on emissions generated by production (called direct emissions), with those emissions generated from the entire system to satisfy the final demands of a good or service (named as Total Effect). Comparing both figures we can know if a very pollutant sector (as is the case of Electricity), is so due to its final demand or due to intermediate demand that other branches make of it so that they can satisfy their final demands. We can also identify which branches, apparently very clean (as some services), are more polluting because the energy need to satisfy its final demands. Finally, these emissions (Total Effect) can be separate into different effects depending on the origin and destination of the generated output, so we calculate the own, internal, feedback, spillover and scale effects.

For all this, we used a SAM Model in which we consider as endogenous, in addition to the productive sectors, accounts for Labour, Capital and Private Consumption. This done, we have separated into two sub-systems, energy and non-energy, applying to both the methodology explained in the previous section, considering only one exogenous final demand (energy or non-energy), and doing zero to its complement.

Table 2 presents the Direct Effect, the emissions due to the production activity of the energy (non-energy) sector, and the Total Effect, that is, the emissions generated to satisfy the final demand of the energy (non-energy) sector. We can also see on this table the impact that both effects have on the emissions due to productive

activities. Finally we present the breakdown of CO₂ emissions for the energy and non-energy subsystems.

A first interesting result is that emissions generated to satisfy the exogenous final energy demand is only 14% of sectoral emissions, while the energy sector generates the higher direct emissions of carbon (with 54.25% of total sectoral emissions) in their productive activity. This is because energy production is intended to satisfy energy and non energy exogenous final demands, and so do emissions.

Within it, the most polluting industries are Electricity (31.6% of sectoral emissions) and Oil Refining (21.8%) as can be seen in the table. However, exogenous final demand of Electricity generate in the economy only a 0.05% of sectoral emissions, being Oil Refining responsible of the most amount of emissions Total Effect for this sub-system, given the significant weight that exports has for this sector, as we see in the table by looking at the high value of the scale effect for this branch.

The negative results obtained for the different effects that are part of the total effect in the case of coal are due to the fact that exogenous final demand consists only of investment, which is negative in this case.

The values obtained for the manufactured gas industry are zero because the exogenous final demand of this industry is zero, so there is no final demand to satisfy more than the endogenized private consumption. It should be noted also in this industry that direct emissions are the lowest in the system, except Oil and Natural Gas in which case emissions are always zero because there is no domestic production.

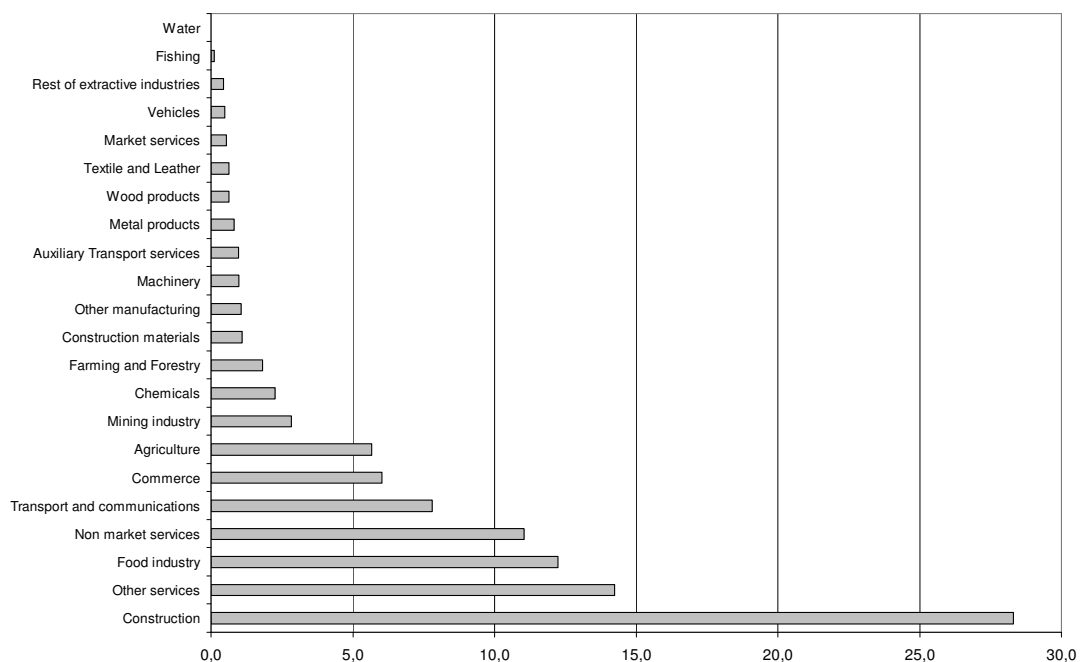
Table 2. Breakdown of total emissions of the energy and non-energy subsystem
(In tons of CO₂)

	Energy subsystem						Non-energy subsystem			
Effects	Coal	Oil and natural gas	Oil Refining	Electricity	Manufactured gas and water steam	Total energy production	Total non-energy production	Consumption	Total non-energy	Total
Own	-6.9	0.0	760,706.1	7,230.7	0.0	767,929.9	1,886,943.3	29,4751.4	2,181,694.8	2,949,624.7
Internal	-7.9	0.0	82,193.6	623.3	0.0	82,809.1	9,823,702.5	2,895,075.3	12,718,777.8	12,801,586.9
Feedback	-2.9	0.0	200,048.2	307.6	0.0	200,352.9	84,647.6	24,570.4	109,217.9	309,570.8
Spillover	-6.1	0.0	361,442.9	528.8	0.0	361,965.6	12,999,277.4	3,803,775.6	16,803,053.0	17,165,018.6
Scale	-78.8	0.0	4,294,759.0	12,613.4	0.0	4,307,293.6	5,981,327.8	727,957.5	6,709,285.3	11,016,578.9
Total	-102.5	0.0	5,699,149.9	21,303.7	0.0	5,720,351.1	30,775,898.5	7,746,130.2	38,522,028.7	44,242,379.8
Direct emissions	348,711.6	0.0	8,893,381.1	12,912,544.5	6,801.2	22,161,438.4	18,685,922.3	3,395,019.1	22,080,941.4	44,242,379.8

Source: Own elaboration.

For the non energy subsystem on the table, we separate the production of Total non-energy production in the columns of non-productive and Consumption. Can be seen that direct emissions are distributed almost 50% between the two subsystems, however, results in the row of Total Effect tells us that most of the emissions from both subsystems are designed to meet non energy final demands, concluding that the energy subsystem is the largest emissions generated in the economy, but they have their origin in the final demands of other branches, as we can see in figure 1. In this figure, we show (as percentage) the emissions generated by the whole system to satisfy the exogenous final demand of the different branches that make up the non-energy subsystem. We can see as Construction and some services are the most polluting branches, followed by Food Industry and Agriculture. In the case of Construction this can be explained because the high value for this account in Gross Capital Formation or Investment.

Figure 1



Source: Own elaboration.

5. Conclusions

The growing concern about the climate change, especially since Stern review (2006), makes it increasingly necessary to conduct economic studies including environment-related issues that can provide some clues and help to define the direction that tax, environmental or economic policies should take if we are to reduce emissions or increase energy efficiency levels.

In this paper we have developed a methodology that is useful for extending the information about CO₂ emissions by the productive sectors of the Andalusian economy, as, apart from identifying the emissions that each productive sector generates in its activity, we are able to ascertain what indirect emissions (generated by other branches) are necessary to satisfy the final demand of each branch.

Calculating these emissions can be helpful for detecting which branches and subsystems are the ones that release most emissions into the atmosphere and, especially, which are the demands that have the biggest pull effect on emissions generated in the economy, plus which are the branches and subsystems most affected by these demands.

We have used the Social Accounting Matrix of the Andalusian economy for the year 1995, which provides statistical support for applying the additive multiplier decomposition methodology (Alcántara and Padilla, 2009) that we developed in section 2 and 3. This additive methodology involves separating the emissions generated by the regional energy (non- energy) subsystem into different effects, identifying which demands are responsible for the output in each case. This way, we get a total effect that is defined as the direct and indirect emissions generated across

the system to satisfy the final demand of each branch of the energy (non energy) subsystem.

In section four, we have divided the subsystems into two groups. The first, composed of the energy branches, is characterized by high scale effect and low spillover effect. On the other hand, non-energy subsystem is characterized by high spillover effect, and lower scale effect.

The second group contains the sectors with a sizeable pull effect on emissions generated by the system, especially the construction and services branches. The first group includes sectors that have a high absorption effect of emissions generated by the system.

As expected, it is the energy subsystem itself that obviously generates most direct emissions, as the energy sectors have the biggest energy intensities and ranks high on direct emissions due to the high energy needs of its production process.

Comparing the results of this total effect against the direct emissions for each of the branches of the Andalusian energy subsystem, we find that the sector that generates the highest levels of direct emissions over emissions due to the total effect is Electricity (7), responsible for almost 1/3 of total sectoral emissions, and the most pollutant branch of the Andalusian productive system. This sector has a sizeable system emissions absorption effect.

About the Total effect emissions, it is remarkable the low emissions in all branches, being the unique significant value that from Oil Refining representing the 99% of the emissions of the energy subsystem.

The results obtained in this study reveal how the productive activity of the regional energy sector, and within it the branches of Electricity and oil Refining

products, is responsible for more than half of all emissions to the atmosphere generated by productive activities. However, this outcome is tempered when we analyze what demands will meet this energy production. The final energy demand is responsible for a low 14% of total emissions, while more expensive to satisfy demands in terms of pollutants in the atmosphere are those of the service sector and construction, being the main energy source used by these very Electricity followed by Oil Refining.

The results of this exercise are potentially useful for extending the, sometimes deficient, information about emissions, apart from providing guidance on policies for application in the future. Note, however, that the difference in emissions can, in some cases, be explained by the subsystems having a greater weight in the economy, as services branches, or by sizeable price differences, as in the case of the energy subsystem.

In the particular case of Electricity, we would recommend a replacement of the more polluting primary energy sources used in the production process, such as coal, with other, less polluting, whether renewable or non-renewable. Finally, the high use some areas of production make Electricity or Refining, and environmental consequences this has, indicate that emissions reductions should not come only from the energy production system, but a more responsible use of energy by the other activities and may establish mechanisms such as enhanced energy plans recently, to prevent the waste of energy and allow greater efficiency in their use.

Models such as the one presented here also have their limitations. One such limitation worth mentioning is the shortage of data or parameter specification. As mentioned earlier, however, they are of great interest to authorities as tools for

simulating different scenarios on which to sound out the effect of specific policies, as they can output ex ante information on the possible effects of a particular policy and ex post information for assessing the impact of such measures.

6. References.

- Alcántara, V., Padilla, E.. 2009. Input-output subsystems and pollution: an application to the service sector and CO₂ emissions in Spain. *Ecological Economics* 68: 905-914.
- Alcántara, V., Roca, J. (1995): "Energy and CO₂ emissions in Spain: methodology of analysis and some results for 1980-90". *Energy Economics*, Vol. 17, Nº 3, pp. 221-230.
- Cardenete, M.A., Moniche, L. (2001): "El nuevo marco Input-Output y la SAM de Andalucía para 1995". *Cuadernos de CC.EE. y EE.* Nº 41, 2001, pp. 13-31.
- Cardenete, M. A., Fuentes-Saguar, P., Polo, C. (2010): "Energy intensities and CO₂ emissions in a SAM model of the Andalusian economy", mimeo.
- Consejería de Medio Ambiente (1997). *Inventario de Emisiones de Andalucía*. Junta de Andalucía.
- Consejería de Medio Ambiente (1995). *La Tabla Input-Output medioambiental de Andalucía 1990*. Junta de Andalucía.
- Heimler, A. (1991): "Linkages and vertical integration in the Chinese economy", *Review of Economics and Statistics*, 73, pp.261-267.
- Instituto de Estadística de Andalucía (1999): *Sistema de Cuenta Económicas de Andalucía. Marco Input-Output 1995. Volume I y II*. Edit. Instituto de Estadística de Andalucía. Sevilla. España.

Kehoe, T.J., Manresa, A., Polo, C., Sancho, F. (1988): “Una Matriz de Contabilidad Social de la Economía española”, Estadística Española, Vol. 30, Nº 117.

Manresa, A., Sancho, F. (2004): “Energy intensities and CO2 emissions in Catalonia: a SAM analysis”, International Journal Environment, Workplace and Employment, Vol. 1, Nº 1, pp. 91-106.

Polo, C. Roland-Holst, D.W., Sancho, F. (1991): “Descomposición de multiplicadores en un modelo multisectorial: Una aplicación al caso español”, Investigaciones Económicas, Vol. XV, nº 1.

Pyatt, G., Round, J. (1979): “Accounting and Fixed Price Multipliers in a Social Accounting Framework”. Economic Journal, Nº 89.

Sánchez Chóliz, J., Duarte, R. (2003): “Analysing pollution by vertically integrated coefficients, with an application to the water sector in Aragon”, Cambridge Journal of Economics, 27, pp. 433-448.

Stern, N. (2006). Stern review: The economics of Climate Change. Cambridge University Press, New York.

Stone, R. (1962): “A Social Accounting Matrix for 1960”. A Programme for Growth. Edit. Chapman and Hall Lid. London.

About the authors:

M. Alejandro Cardenete (macardenete@upo.es) is Associate Professor at the Department of Economics, Universidad Pablo de Olavide, Seville.

Patricia D. Fuentes-Saguar⁵ (pfuesag@upo.es) is Assistant Professor at the Department of Economics, Universidad Pablo de Olavide, Seville.

Clemente Polo (clemente.polo@uab.es) is Professor at the Department of Economics and Economic History, Universidad Autònoma de Barcelona, Barcelona.

¹ The same partition can be explained for the non-energy subsystem using (12).

² The interested reader can find a detailed description of the procedure followed to calculate the two emission coefficients in value units using the physical and value input-output tables of 1985 and the Eurostat physical emission coefficients for each energy commodity.

³ The corresponding figures 42,023.0, 39,173.7 and 2,849.3 kt. in the Emissions Inventory of Andalusia by the Environmental Department (1997) are lower than those estimated by Cardenete, Fuentes-Saguar and Polo. The estimates in the Environmental Input-Output Tables of Andalusia (Consejería de Medioambiente, 1995) are even closer.

⁴ It includes endogenous private consumption and the exogenous public consumption and gross capital formation and excludes exports.

⁵ Postal Address: Departamento de Economía. Universidad Pablo de Olavide. Carretera de Utrera, km. 1, 41013 Sevilla. Spain.