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INPUT–OUTPUT SUBSYSTEMS AND POLLUTION: AN APPLICATION TO THE SERVICE SECTOR AND CO_2 EMISSIONS IN SPAIN

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Abstract

The analysis of input–output subsystems provides a useful tool for studying the productive structure of the different sectors of an economy. In this paper we develop this analysis to the study of the CO_2 emissions associated to the group of branches of the service sector. The decomposition of the total production of the services subsystem allows us to decompose the CO_2 emissions into five different components (own, demand volume, feed-back, internal and spill over components). From the results obtained, we can highlight the different roles played by the different branches of services. Transport activities are the services with the highest level of the direct emissions generated in the production of the sector. These activities are required by the other sectors of the economy to a greater degree than they are for their own final demand. Therefore, the production sold to other sectors causes more emissions than its own final demand. However, in the case of other service activities, direct and indirect emissions related to final demand are much more important, due to the strong pull effect of service activities on other activities of the economy. In this respect, Wholesale and retail trade, Hotels and restaurants, Real estate, renting and business activities, and Public

Administration services should be highlighted. These services receive scarce attention in the design of policies aimed at reducing emissions, but are notably responsible for the major increase in emissions experienced in recent years.

Keywords: CO_2 emissions; input–output analysis; service sector; Spain; subsystems.

1. Introduction

The evolution of CO_2 emissions in Spain has moved away from the goal established by European Directive 2002/358/EC, which ratified the Kyoto Protocol and limited the increase in greenhouse gas emissions in Spain to 15% on average for the years 2008–2012 with respect to those of 1990. In 2006 the emissions of the six gases considered by the Protocol were 48.05% higher than they were in 1990 (Santamarta and Nieto, 2007)[1].

It is evident that the policies implemented in recent years have not been good enough to reduce the increase in emissions. Of the measures implemented, the National Allocation Plan must be highlighted. This plan fulfils directive 2003/87/CE on the market of emission allowances, which has forced certain sectors to control their CO_2 emissions since January 1st, 2005. However, one of the sectors that has been most decisive in the increase in emissions of recent years, the service sector, is not directly affected by the directive[2]. Transport, trade and other services, along with the domestic sector, are diffused emission focuses whose emissions and use of energy are not regulated by any normative[3].

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[1] Emissions measured in tons of CO_2-equivalent employing conversion factors of IPCC. The six gases considered are CO_2, N_2O, CH_4, HFCs, CFCs, and SF_4.

[2] Nevertheless, as noted by a reviewer, the Emissions Trading Directive requires Member States to mention in their National Allocation Plans what measures will be applied in this sector.

[3] However, their indirect emissions might be affected (e.g., many indirect emissions of the service sector are produced in electricity generation, which is affected by the directive).

There is the false perception that the service sector is an environment friendly sector. But there are multiple activities in the service sector, and some of these have serious impacts on the environment. Alcántara (2007) shows the major relevance of the service sector in the increase in emissions experienced between 1987 and 2002 in Spain, where it was responsible for about 40% of this increase[4].

Several studies have used an input–output methodology to analyze the structure of CO_2 emissions or energy consumption. Input–output analysis allows us to identify the direct and indirect emissions associated with the production of each sector and so identify the impact of a change in the final demand of the different sectors on total or sectoral emissions (see e.g., Proops, 1988; Lenzen, 1998; Machado et al., 2001; Reinert and Roland-Holst, 2001; Mongelli et al., 2006)[5]. Some authors have analyzed CO_2 emissions or energy consumption in Spain using an input–output framework (see e.g., Pajuelo, 1980; Alcántara and Roca, 1995; Labandeira and Labeaga, 2002; Alcántara and Padilla, 2003; Sánchez-Chóliz and Duarte, 2004; Butnar and Llop, 2006; Tarancón and del Río, 2007a,b). In a recent study, in which the direct and indirect impact on CO_2 emissions of 45 sectors are computed, Wholesale and retail trade appears as a key sector, together with Transport, Manufacture of non-metallic minerals, Real estate, and other sectors of less importance (Alcántara and Padilla, 2006). Other recent study analyzing sector linkages and CO_2 emissions for the Spanish case is the one by Tarancón and del Río (2007a), which proposes a methodology to distinguish direct from indirect emissions and highlight the important role played by some service activities such as

[4] The author shows that, according to IEA (2004) data on emissions from fuel combustion, transport emissions increased from accounting for 28.9% of total emissions in 1986 to a 35.8% in 2003, while other services and trade increased their relative importance from 7.6% to 11.0%.

[5] Within the framework of input–output analysis, structural decomposition techniques have been employed to explain the changes in CO_2 emissions between two periods (see e.g., Chang and Lin, 1998; Kagawa and Inamura, 2001; Alcántara and Duarte, 2004; Tarancón and del Río, 2007c).

Terrestrial transport, Commercial sector, and Hotel business. The last two key sectors buy inputs from very polluting sectors (or from sectors that are buyers from polluting sectors), while transport is a key sector because the increase in the final demand of several sectors leads to a significant increase in transport emissions.

Given the importance of services in explaining the recent evolution of CO_2 emissions and considering the perspective of the growing importance of the sector, a detailed analysis of the sector is of major relevance; an analysis studying the factors that explain its important impact on CO_2 emissions[6]. In order to make this analysis we will employ the analytical tool provided by subsystems methodology in the framework of input–output analysis. This tool will allow us to study the importance of the service sector as a whole in the economic system, as well as analyze the role played by its different activity branches and their relationship with other productive sectors. Section 2 develops this methodology and its application to the analysis of CO_2 emissions. Section 3 applies the methodology and shows and discusses the results. Section 4 summarizes the main conclusions of the paper.

2. Methodological proposal

In the framework of input–output analysis, the study of a particular sector, or a group of sectors, without delinking it from the rest of the system, might be made by treating this sector or sectors as a subsystem generating a single final output, the output of the sector or sectors. An analysis of this kind was developed from an economic and environmental perspective in Alcántara (1995). Later, Sánchez Chóliz and Duarte (2003), following this methodology extended the original proposal. Our approach is partly based on the proposal made by these

[6] Which is even more so if we take into account the new objectives established by the European Union, which imply a 20% reduction by 2020, and the goal that this will ultimately imply for Spain will be hard to accomplish without more effective measures involving those sectors that until now have not been firmly tackled by the policies applied.

authors and we also use a previous methodology developed by Heimler (1991) for the decomposition of an input–output matrix into sector groups.

The artifact of subsystems was pioneered by Sraffa (1960), in Appendix A of his book. The concept of the subsystem is relatively simple. As Sraffa stated, if we consider a system of industries in which any one industry produces a different commodity (as occurs in an input–output table), "such a system can be subdivided into as many parts as there are commodities in its net product, in such a way that each part forms a smaller self-replacing system the net product of which consists of only one kind of commodity. These parts we shall call 'sub-systems'" (p. 89).

The first proposal on subsystems construction was developed by Harcout and Massaro (1964). From a theoretical perspective the works by Pasinetti (1973, 1986 and 1988), Sinisalco (1982), Deprez (1990) and Scazzieri (1990) are quite relevant. Several proposals and analyses based on the subsystem concept have been developed in applied economics analysis. Although the analyses developed are not related with the analysis of environmental impacts, some of these works might be highlighted, such as the ones by Gossling and Droving (1966), Rampa and Rampa (1982), Rocherieux (1983) and Gregory and Russo (2004), among others.

A subsystem allows us to see the specific productive structure of each of the *n* sectors of the economic system. It is an analytical unit extracted from the economic system as a whole, which can be studied as a particular unit maintaining the own characteristics of the system. With the words of Sinisalco (1982) "a subsystem is a unit that groupes all the activities, from all the activity branches, direct and indirectly used for satisfying the final demand of a given commodity. In a context of interdependent productive branches, a subsystem includes then a set of activities that belong to different branches as a 'reconstruction' by *vertical integration* of all the productive process that (ideally) gives place to a specific commodity for final use".

Therefore, this analytical tool is of major interest in the study of the polluting emissions of a sector or a group of sectors, linked to their production processes. In our case, we will use this tool to study the CO_2 emissions (the most important of the greenhouse gases) associated to the branches of the service sector of the Spanish economy. This tool will allow us to study the importance of the service sector as a whole in the economic system, as well as to analyze the role played by its different activity branches and their relationship with other productive sectors. In this way, it improves and complements the view of the polluting behavior of the sector and its subsectors that we would have had with a conventional input–output analysis.

Although the proposed methodology is based on that developed in Alcántara (1995), we develop some changes that improve it in terms of its potential results. We refer the interested reader to this work, in which there is a wider discussion of both the theoretical basis of the methodology, and of the previous developments in non environmental analytical frameworks.

In order to help the reader, we define the variables and parameters used:

A: Matrix (n x n) of technical coefficients of the Leontief model. The economic system is composed of n sectors that belong to set N.

N = (1, 2, ..., m, ..., n), where 1, 2, ..., m are the m subsectors not belonging to the service sector and m+1, ..., n are the s subsectors of the service sector (s = n-m).

I: Identity matrix (n x n).

$\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$: Leontief inverse matrix (n x n).

$\mathbf{x}^M$: column vector (m x 1) which denotes the production of the m subsectors which do not belong to the service sector.

$\mathbf{x}^S$: column vector (s x 1) which denotes the production of the s subsectors which belong to the service sector.

$\mathbf{y}^M$: column vector (m x 1) which denotes the final demand of the m subsectors which do not belong to the service sector.

$\mathbf{y}^S$: column vector (*s* x *1*) which denotes the final demand of the s subsectors that belong to the service sector.

The actual production and the final demand of the economy might now be expressed as:

$\mathbf{x} = \begin{pmatrix} \mathbf{x}^M \\ \mathbf{x}^S \end{pmatrix}$ is the production vector (*n* x *1*).

$\mathbf{y} = \begin{pmatrix} \mathbf{y}^M \\ \mathbf{y}^S \end{pmatrix}$ is the final demand vector (*n* x *1*).

If we make an analogous separation in matrixes **B** and **A**, we obtain:

$\mathbf{B} = \begin{pmatrix} \mathbf{B}_{MM} & \mathbf{B}_{MS} \\ \mathbf{B}_{SM} & \mathbf{B}_{SS} \end{pmatrix}$ and $\mathbf{A} = \begin{pmatrix} \mathbf{A}_{MM} & \mathbf{A}_{MS} \\ \mathbf{A}_{SM} & \mathbf{A}_{SS} \end{pmatrix}$

(^) denotes the diagonalization of a vector.

(′) denotes the transposition of a vector or matrix.

2.1. Construction of services subsystem and decomposition of its production into different components

We can start our methodological approach by expressing the Leontief model in the following way:

$$\begin{pmatrix} \mathbf{A}_{MM} & \mathbf{A}_{MS} \\ \mathbf{A}_{SM} & \mathbf{A}_{SS} \end{pmatrix}\begin{pmatrix} \mathbf{x}^M \\ \mathbf{x}^S \end{pmatrix} + \begin{pmatrix} \mathbf{y}^M \\ \mathbf{y}^S \end{pmatrix} = \begin{pmatrix} \mathbf{x}^M \\ \mathbf{x}^S \end{pmatrix} \tag{1}$$

a well-known system of equations, whose solution is given by:

$$\left[\begin{pmatrix} \mathbf{I} & 0 \\ 0 & \mathbf{I} \end{pmatrix} - \begin{pmatrix} \mathbf{A}_{MM} & \mathbf{A}_{MS} \\ \mathbf{A}_{SM} & \mathbf{A}_{SS} \end{pmatrix}\right]^{-1}\begin{pmatrix} \mathbf{y}^M \\ \mathbf{y}^S \end{pmatrix} = \begin{pmatrix} \mathbf{B}_{MM} & \mathbf{B}_{MS} \\ \mathbf{B}_{SM} & \mathbf{B}_{SS} \end{pmatrix}\begin{pmatrix} \mathbf{y}^M \\ \mathbf{y}^S \end{pmatrix} = \begin{pmatrix} \mathbf{x}^M \\ \mathbf{x}^S \end{pmatrix} \tag{2}$$

Substituting the value obtained for **x** in the left hand side of (1), it becomes:

$$\begin{pmatrix} \mathbf{A}_{MM} & \mathbf{A}_{MS} \\ \mathbf{A}_{SM} & \mathbf{A}_{SS} \end{pmatrix}\begin{pmatrix} \mathbf{B}_{MM} & \mathbf{B}_{MS} \\ \mathbf{B}_{SM} & \mathbf{B}_{SS} \end{pmatrix}\begin{pmatrix} \mathbf{y}^M \\ \mathbf{y}^S \end{pmatrix} + \begin{pmatrix} \mathbf{y}^M \\ \mathbf{y}^S \end{pmatrix} = \begin{pmatrix} \mathbf{x}^M \\ \mathbf{x}^S \end{pmatrix} \tag{3}$$

This expression decomposes the production into final production and productive inputs needed to obtain the final production. Notice that the inputs needed to obtain the final demand are given as a lineal combination of it.

If $\mathbf{y}^M = \mathbf{0}$, expression (3) might be rewritten as:

$$\begin{pmatrix} \mathbf{A}_{MM} & \mathbf{A}_{MS} \\ \mathbf{A}_{SM} & \mathbf{A}_{SS} \end{pmatrix} \begin{pmatrix} \mathbf{B}_{MM} & \mathbf{B}_{MS} \\ \mathbf{B}_{SM} & \mathbf{B}_{SS} \end{pmatrix} \begin{pmatrix} 0 \\ \mathbf{y}^S \end{pmatrix} + \begin{pmatrix} 0 \\ \mathbf{y}^S \end{pmatrix} = \begin{pmatrix} \mathbf{x}_S^M \\ \mathbf{x}_S^S \end{pmatrix} \tag{4}$$

Where $\mathbf{x}^M{}_S$ is the production of non-service subsectors for providing the final demand of services and $\mathbf{x}^S{}_S$ is the production of service subsectors for providing the final demand of services.

This expression shows the production needed to obtain the final output of the service sector. According to what we said earlier, expression (4) is no more than the matrix image of the services subsystem. From expression (4) we can operate a decomposition of production into a group of components; as stated in Alcántara (1995; 1999). For this, we decompose technical coefficients matrix $\mathbf{A}$ into two matrixes, $\mathbf{A}^D$ and $\mathbf{A}^0$, so that $\mathbf{A} = \mathbf{A}^D + \mathbf{A}^0$. Where $\mathbf{A}^{\mathrm{D}}$ is a matrix (n x n) whose main diagonal contains the elements of matrix $\mathbf{A}$ and the rest of elements are zeros. Matrix $\mathbf{A}^0$ (n x n) contains the rest of elements of matrix $\mathbf{A}$ and has zeros in its main diagonal. Expression (4), then, could be written as:

$$\left[\begin{pmatrix} \mathbf{A}_{MM}^D & 0 \\ 0 & \mathbf{A}_{SS}^D \end{pmatrix} + \begin{pmatrix} \mathbf{A}_{MM}^O & \mathbf{A}_{MS}^O \\ \mathbf{A}_{SM}^O & \mathbf{A}_{SS}^O \end{pmatrix} \right] \begin{pmatrix} \mathbf{B}_{MM} & \mathbf{B}_{MS} \\ \mathbf{B}_{SM} & \mathbf{B}_{SS} \end{pmatrix} \begin{pmatrix} 0 \\ \mathbf{y}^S \end{pmatrix} + \begin{pmatrix} 0 \\ \mathbf{y}^S \end{pmatrix} = \begin{pmatrix} \mathbf{x}_S^M \\ \mathbf{x}_S^S \end{pmatrix} \tag{5}$$

Operating:

$$\begin{aligned} &\mathbf{A}_{MM}^D \mathbf{B}_{MS} \mathbf{y}^S + \mathbf{A}_{MM}^O \mathbf{B}_{MS} \mathbf{y}^S + \mathbf{A}_{MS}^O \mathbf{B}_{SS} \mathbf{y}^S + \mathbf{0} = \mathbf{x}_S^M \\ &\mathbf{A}_{SS}^D \mathbf{B}_{SS} \mathbf{y}^S + \mathbf{A}_{SM}^O \mathbf{B}_{MS} \mathbf{y}^S + \mathbf{A}_{SS}^O \mathbf{B}_{SS} \mathbf{y}^S + \mathbf{y}^S = \mathbf{x}_S^S \end{aligned} \tag{6}$$

The first matrix equation in (6) gives us the vector of the production that the sectors that do not belong to the service sector have to obtain in order to make the final demand of the service sector possible. We can consider this result to be a **spill over component**.

The second equation shows the vector of service sector production for the service subsystem itself. Observing the four vectors on the left hand side of this equation, we see that the service sector output for the service subsystem itself can be decomposed into four components. The first one, which we will call the **demand volume component** is shown by the final demand vector $\mathbf{y}^S$ and depends only on the level reached by the demand for the different services. The first summand on the left hand side of the equation, $\mathbf{A}_{SS}^{D}\mathbf{B}_{SS}\mathbf{y}^{S}$, shows the quantity of own inputs that each of the activity branches of the service subsystem needs to obtain its own final demand. We will call this the **own component**. Notice that the diagonalization of $\mathbf{y}^S$ in the former expression would lead to the following diagonal matrix:

$$\mathbf{A}_{SS}^{D}\mathbf{B}_{SS}\hat{\mathbf{y}}^{S} \qquad (7)$$

Whose elements denote each service subsector's production of inputs that are used in the same subsector[7].

The second summand on the left hand side of the second equation in (6) shows what we call the **feed-back component**. That is, the production of inputs that each subsector of the service sector has to produce for non-service sectors, so that these obtain the output that the service sector demands to them. The impact of each of the service subsectors on the other service branches, as regards their structural relationships with non-service sectors, is determined by diagonalizing $\mathbf{y}^S$ in the second summand of the equation:

$$\mathbf{A}_{SM}^{o}\mathbf{B}_{MS}\hat{\mathbf{y}}^{S} \qquad (8)$$

[7] The terms "activity branches" and "subsectors" are used interchangeably.

Finally, the third summand on the left hand side of the second equation shows the production required by service subsectors from other subsectors of the service subsystem. This vector can then be considered an *intra* spill over effect that we will call **internal component**. Diagonalizing $\mathbf{y}^S$:

$$\mathbf{A}^o_{SS}\mathbf{B}_{SS}\hat{\mathbf{y}}^S \tag{9}$$

we obtain the production required by each branch of the service subsystem from the subsystem itself. Then, the characteristic element of this matrix shows the output of service subsector *g* used in service subsector *h*.[8]

2.2. CO_2 emissions generated by the service subsystem

Let $\mathbf{c}^M$ be a (m x 1) vector of CO_2 emissions generated per unit of output by the different subsectors of non-service sectors. Let $\mathbf{c}^S$ be a (s x 1) vector that denotes the emission units of the service subsectors. The different components into which we have decomposed the total (direct and indirect) production of the service subsystem can be now expressed in terms of CO_2 emissions associated with this production. To do this, we proceed in the following way:

Demand volume component:

Is given, for the whole subsystem, by the expression,

$$DVC = \mathbf{c}^{S\prime}\mathbf{y}^S \tag{10}$$

And, for subsectors, we would get the following vector:

$$\mathbf{e}'_{DVC} = \mathbf{c}^{S\prime}\hat{\mathbf{y}}^S \tag{11}$$

Own component:

The total own component would be given by the following expression:

[8] Moreover, the main diagonal of matrix (9) constitutes an internal feed back in the subsystem. However, we will not develop this separation.

$$OC = \mathbf{c}^{S\prime}\mathbf{A}_{SS}^{D}\mathbf{B}_{SS}\mathbf{y}^{S} \qquad (12)$$

And, for each of the subsectors, by the expression:

$$\mathbf{e}_{OC}^{\prime} = \mathbf{c}^{S\prime}\mathbf{A}_{SS}^{D}\mathbf{B}_{SS}\hat{\mathbf{y}}^{S} \qquad (13)$$

Feed-back component:

Following the above reasoning, the total level of emissions associated to this component would be:

$$FBC = \mathbf{c}^{S\prime}\mathbf{A}_{SM}^{O}\mathbf{B}_{MS}\mathbf{y}^{S} \qquad (14)$$

And for the different subsectors it would be given by the following expression:

$$\mathbf{e}_{FBC}^{\prime} = \mathbf{c}^{S\prime}\mathbf{A}_{SM}^{O}\mathbf{B}_{MS}\hat{\mathbf{y}}^{S} \qquad (15)$$

Spill over component:

The levels of total emissions and of subsector emissions now depend on the direct emission coefficients of non-service subsectors. Therefore, the total level would be:

$$SOC = \mathbf{c}^{M\prime}\left(\mathbf{A}_{MM}^{D}\mathbf{B}_{MS} + \mathbf{A}_{MM}^{O}\mathbf{B}_{MS}\mathbf{y}^{S} + \mathbf{A}_{MS}^{O}\mathbf{B}_{SS}\right)\mathbf{y}^{S} \qquad (16)$$

And, for the different subsectors:

$$\mathbf{e}_{SOC}^{\prime} = \mathbf{c}^{M\prime}\left(\mathbf{A}_{MM}^{D}\mathbf{B}_{MS} + \mathbf{A}_{MM}^{O}\mathbf{B}_{MS}\mathbf{y}^{S} + \mathbf{A}_{MS}^{O}\mathbf{B}_{SS}\right)\hat{\mathbf{y}}^{S} \qquad (17)$$

Internal component:

The total level of emissions generated in the production of service subsectors that are used as inputs by other service subsectors is given by the next expression:

$$IC = \mathbf{c}^{S\prime}\mathbf{A}_{SS}^{O}\mathbf{B}_{SS}\mathbf{y}^{S} \qquad (18)$$

And, for the different branches of services sector[9]:

[9] The diagonalization of vector $\mathbf{c}^{s'}$ would give place to a matrix whose main diagonal would be the feed-back on each one of the productive branches of the service subsystem regarding their sales to other branches of the same subsystem. We will not operate this decomposition in our work.

$$\mathbf{e}'_{IC} = \mathbf{c}^{S\prime}\mathbf{A}^{O}_{SS}\,\mathbf{B}_{SS}\,\hat{\mathbf{y}}^{S} \tag{19}$$

Total (direct and indirect) emissions (E) generated in the production of the final output of the service subsystem would be given by:

E = DVC + OC + FBC + SOC + IC (20)

Notice that, from the view of subsystems, we can also determine the direct emission generated by the service subsystem production for the production of non-service subsectors. This can be done by using expression (3) and computing the emission generated for the final production vector of non-service subsectors. That is, if $\mathbf{y}^S = \mathbf{0}$, expression (3) might be rewritten as:

$$\begin{pmatrix} \mathbf{A}_{MM} & \mathbf{A}_{MS} \\ \mathbf{A}_{SM} & \mathbf{A}_{SS} \end{pmatrix}\begin{pmatrix} \mathbf{B}_{MM} & \mathbf{B}_{MS} \\ \mathbf{B}_{SM} & \mathbf{B}_{SS} \end{pmatrix}\begin{pmatrix} \mathbf{y}^{M} \\ 0 \end{pmatrix} + \begin{pmatrix} \mathbf{y}^{M} \\ 0 \end{pmatrix} = \begin{pmatrix} \mathbf{x}^{M}_{M} \\ \mathbf{x}^{S}_{M} \end{pmatrix} \tag{21}$$

Operating, the following expression would give the vector of production generated by the services subsystem for the rest of the system:

$$\mathbf{A}_{SM}\,\mathbf{B}_{MM}\,\mathbf{y}^{M} + \mathbf{A}_{SS}\,\mathbf{B}_{SM}\,\mathbf{y}^{M} + 0 = \mathbf{x}^{S}_{M} \tag{22}$$

The CO_2 emissions generated by the service subsectors for the production of non-service sectors are given by the following expression:

$$E_{\text{for other sectors}} = \mathbf{c}^{S\prime}\,\mathbf{x}^{S}_{M} \tag{23}$$

3. Application and results

3.1. A general view of the service sector

According to the data provided by the INE in its environmental accounts, produced following the NAMEA (National Accounting Matrix including Environmental Accounts), total CO_2 emissions for the year 2000 were 303,984 kt., from which, 55,292 kt. were emitted by family units, including private transport, and 248,692 kt. were emitted by productive sectors. We should also consider that, according to NAMEA's accounting criteria, the emissions generated as a result of the transport activities undertaken by different activity branches by their own means of transport are imputed to these subsectors, and not to land transport, which also includes rail transport. Our comments, and the percentages for total emissions shown below, refer to the 248,692 kt. generated by productive sectors.

In order to start from a general view of the situation of the service subsectors, we have created Table 1.

TABLE 1 HERE

Total (direct and indirect) emission generated by all productive sectors to satisfy the final demand of the service sector was more than one third (35.2%) of the emission generated by all the productive sectors in 2000. The direct emissions generated in the sector's production amounted to only 17.5% of these emissions, a much lower percentage. Therefore, we see that the pull effects of the service sector on emissions are of major importance; total emissions caused by its final demand being more than double of the emissions directly generated in the production of services. However, as shown in the table, the role played by the different service subsectors is very different.

With respect to the direct emissions generated in the production of the different subsectors, we could highlight the level of emissions by the transport subsectors, Land transport being the subsector with the highest level of direct emissions, with 7.8% of total emissions. The second subsector is Air transport, with 3.0%. Of much lower relative importance is the Wholesale, retail trade and repair of vehicles and goods subsector, with 2.1%. However, if we only consider the direct emissions generated in each subsector production, we obviate the fact that a large number of the emissions of some subsectors are emitted to facilitate the production of other subsectors. In other words, we would obviate that some subsectors' production requires the production of goods and services provided by other subsectors, in such a way that it pulls emissions in other subsectors that are often higher than the direct emissions generated in the subsector's production.

In this sense, we could highlight the different relative importance of the transport subsectors in terms of direct emissions with respect to total emissions generated to satisfy their demand. While in terms of direct emissions transport subsectors account for 11.9% of emissions, in terms of total emissions (direct and indirect emissions to satisfy their final demand) the relative importance of these services is only 7.7%. It is especially remarkable to note the lower relative importance of Land transport, which represents 7.8% of direct emissions and only 4.3% of total emissions, descending from first to third place in importance among the subsectors. This shows the greater extent to which the transport subsectors produce for the other productive activities, which have a need for their services and therefore cause transport to emit CO_2 to satisfy their demands.

Moreover, Table 1 clearly shows the importance of other service subsectors, as they pull and are responsible for a good part of the emissions generated in other sectors. In short, we could highlight the case of Wholesale and retail trade and repair of vehicles and goods. Direct emissions generated in its production represent only 2.1% of emissions, while this subsector is responsible for 7.4% of total emissions. The same happens in the case of Hotels and restaurants, 1.1% and 5.7%, Real estate, renting and business activities, 0.2% and 4%, or Public Administration, 0.4% and 2.9%. In fact, apart from transport services, the other services have greater absolute and percentage emissions when total (direct and indirect) emissions caused by their demands are considered than when only the emissions that are directly generated in their production are considered.

The service sector, in global terms, is a sector that considerably pulls the other sectors of the economy and, therefore, its growth leads to a considerable increase in the emissions of other sectors. However, if we consider the service sector as a whole, we lose the perspective of the different roles that transport and other services play in the economy. Moreover, depending on the productive structure of the economy, transport services might hide the strong pull effect of other service activities. It is therefore convenient to make a detailed analysis of the behavior of the different service subsectors in order to draw conclusions regarding their impact on emissions, the causes of these emissions and, therefore, to obtain information that can act as guidelines for future energy and climate policies.

In the following section, we employ the methodology developed in the previous section to analyze the importance of the different factors described in the evolution of the emissions caused by the different subsectors of the service subsystem.

3.2. Analysis of the service subsystem

We will first comment the global result for the service subsystem. We will then be able to study the contribution made by each subsector to the total, analyzing the particular role played by the different subsectors that constitute the service sector. The results obtained after the computation of expressions (10)–(20) are shown in Table 2.

TABLE 2 HERE

As we proposed in Section 2, total emissions are decomposed into five components, four of which are associated with the internal functioning of the sector. First, what is called **demand volume component**, which depends only on the level of service sector demand and its direct emissions. The demand volume component amounts to 10% of the total emissions of all sectors, including service and non-service subsectors. This is a low percentage, in relative terms, which does very little to explain the importance of the service sector in total CO_2 emissions.

As for what we have called the **own component**, which depends on the demand of each service subsector's own services to satisfy its demand, and the **feed-back component**, which depends on the relationship between the service sector and the rest of the economy as a supplier, these effects do not justify the major responsibility of the service sector for the total emissions of productive sectors. These two effects only amount to 1.0% of these emissions. As for the **internal component**, which depends on the impact of any service subsector on the rest of service subsectors, it amounts to 2.4% of total emissions of productive sectors.

In the **spill over component** we find an explanation for the importance of the service sector. This effect is no more than the result of the backward linkages of the service subsectors (i.e. the pull effects of these subsectors). Moreover, it is a pure backward linkage (see Sánchez Chóliz and Duarte, 2003). This effect amounts to 21.7% of the total emissions of all productive sectors. If we take into account the fact that the direct emission generated by non-service sectors amounted to 205,292 kt of CO_2 in the year 2000 and that the *spill over* component of the service sector emission amounts (as shown in Table 2) to 54,037.1 kt., this means that 26.3% of the emissions generated by non-service subsectors (more than a quarter) are incorporated into the final production of the service sector.

These results are not unusual. As stated in Alcántara (2007), services support their activity on a material basis, but there is the "false belief that a services economy, which is expressed by a greater growth of the valued-added of their sectors with respect to the industrial sectors, is a dematerialized economy" (p. 63).

As we have previously observed, not all the branches of the service sector are of the same importance. We have also highlighted the need to study the specific behavior of each service without obviating its relationship with the economic system as a whole. We will now analyze the results, shown in Table 2, for the different subsectors.

The own component, as we said earlier, is of minor relevance to the service subsectors. The subsectors for which this effect is of greater importance are Wholesale and retail trade, and repair of vehicles and goods, and to a lesser extent transport subsectors. However, even in these cases, this component is of very small magnitude in relation to the other components.

As for the feed-back component, we can cite the case of Hotels and restaurants, which represents 32.6% of the total of this effect. As regards the internal component, the sector of Wholesale and trade is the most remarkable one as it represents more than one third (34.8%) of the total of this effect.

Spill over is the component of greatest interest, given the importance of services in pulling other sectors, as we explained earlier. This component clearly demonstrates the pull effects of the different subsectors, as it differentiates them from the pull effects on the own sector (own and feed-back components). Again, we could highlight the role played by the Wholesale and retail trade, and repair of vehicles and goods sector, which is responsible for 22.5% of this component. This means that 7.9 % of the CO_2 emissions of all productive sectors are due to the pull effect of the activities of this subsector. Other sectors with a noticeable role in this component are Hotels and restaurants (19.5%) and Real estate, renting and business activities (15.9%). We could also highlight the pull effect of Public administration and Other community, social and personal service activities. Despite the major responsibility of these activities in the generation of emissions, they are rarely affected by the measures applied to control emissions.

However, in the case of transport, the pull effects are relatively small. Land transport amounts to only 4.2% of the total spill over component caused by the different service subsectors. The fact that the emissions caused by the production oriented towards sales to other subsectors and to other sectors are greater than the demand component of transport services shows that transport is strongly pulled by the services that demand the other productive activities. This factor is more important in explaining the emissions of these activities than that of the transport services' own final demand. When analyzing the problem of transport emissions one has to consider how the needs of transport services by other productive activities can be modified. However, to properly consider the problem of transport we need the full data on transport activities, in order to know which transport emissions are generated in other productive activities that produce these services by themselves. Unfortunately, this data is not available.

These results confirm the findings by Tarancón and del Río (2007a), who proposed a methodology to distinguish direct and indirect emissions and highlighted the key importance of some services such as Terrestrial transport, Commercial sector and Hotel business. They found that the last two sectors buy inputs from very polluting sectors (or from sectors that are buyers from polluting sectors), and that the final demand of several sectors leads to a significant increase in transport emissions.

We have produced Table 3 in order to analyze in more detail the spill over component. This table distributes the emissions associated with this component according to the service subsectors that pull other sectors and to the main sectors which are pulled.

TABLE 3 HERE

As shown in Table 3, of the 54,037.1 kt. of CO_2 that this component amounts to, 63.1% corresponds to emissions generated by the consumption of gas and electricity. Of that percentage, Wholesale and retail trade, and repair of vehicles and goods amount to 17.4%, Hotels and restaurants amount to 8.1%, Real estate, renting and business activities amount to 9.3%, and Public Administration amounts to 8.4%. The remainder subsectors amount to much lower percentages, apart from Health and social work, which amounts to 4.1%, and Other community, social and personal service activities subsectors, which amounts to 4.6%. This is due to the fact that, in the case of the service sector, in general, and especially in the aforementioned subsectors, a major amount of energy consumption is related to the structure and uses of buildings. It is certain that, in some cases, there is no other solution than to use energy in a continuous way, e.g. for illumination, but in other cases this continued use can only be explained by the presence of a building that was planned in accordance with criteria that ignored environmental concerns. Of the scarce measures applied that affect these service subsectors in some way, we find the new Edification Technical Code. This regulation makes compulsory, from 2006, the installation of energy saving measures and the adaptation of buildings for the integration of solar energy. However, we have to take into account the fact that that code is only applied to the thermal conditions of new buildings, and does not affect those that have already been built. The Spanish Energy Efficiency Strategy promotes energy efficiency measures in several sectors, including commercial establishments, although the expected increase in the installation of air conditioning devices in commercial buildings will work against the reduction in energy consumption (Tarancón and del Río, 2007a). As regards the emissions generated in the production of electricity, the promotion of changes in the electricity generation mix is a key strategy for its reduction. The Renewable Energy Promotion Plan might be highlighted as a measure that can contribute to this. However, the projections of a continued increase in electricity demand cast doubts on the effectiveness of the measures implemented. Therefore, the aforementioned importance of some services activities in the electricity demand should be taken into account in the design of energy and emissions mitigation policies in order to achieve an effective combination of public policies to tackle the problem.

As for the consumption of petrol products and, to a lesser extent of coal, this productive subsector is affected by the service sector by 8.1% of total service sector emissions. This percentage may seem low in comparison with the pulling effect of the service sector on electricity and gas. This is mainly explained by the fact that the main consumer of petrol products is transport and, of the different transport subsectors, Land transport is the most important. As we highlighted in Table 2, transport sectors are linked to CO_2 emissions through their direct emissions, not through the pull effect of these subsectors on other productive activities, so this explains their low spill over component. In any case, transport activities would be pulled by other productive activities of the economy, as well as by their final demand for personal transport or commodity transport. Moreover, as we said earlier, it should not be forgotten that CO_2 emissions linked to the transport of firms' own commodities are included in the corresponding sector following the criteria of the NAMEA accounts system. And private road transport is included in the domestic sector. Although we do not have information about these emissions, the important role played by transport in CO_2 emissions in Spain is quite clear. Therefore, taking into account our results, the policies for mitigating transport emissions should be designed specifically for this sector. The measures should be oriented to reduce the needs for transport services by other productive sectors as well as to change their demands to less polluting ways of transport. It must be highlighted that road transport is the transport mode which has experienced the largest growth in last decades in Spain and that it currently accounts for a much greater share of the transport of goods than it does in other European countries.

Excluding transport services, the spill over component—the emissions caused by service subsector's demand for other (service and non-service) productive activities—is much higher than the emissions generated by the production of services for other sectors. The services are therefore productive activities that are more responsible for the level of total emissions than what is usually assigned to them a priori.

Given the growing weight of the service subsectors in the economy, action in relation to these activities is imperative, both in terms of the emissions that are directly generated in their production as well as the productive structure that lead some service activities to require the consumption of a large quantity of energy in other sectors' production in order to satisfy their demand.

4. Conclusions

Within the framework of input–output analysis, subsystems analysis allows us to study the productive structure of each of the sectors of an economy. Using this tool we have studied the CO_2 emissions associated with the set of productive branches (subsectors) of the service sector. The decomposition of the total production of the service subsystem into different components has allowed us to obtain the CO_2 emissions related with these components. The application of subsystems tool has allowed us to study the importance of the service sector as a whole in the economic system as well as to analyze the role played by its different activity branches and their relationship with other productive sectors. This analysis improves and complements the picture of the sector that we would have had with a conventional input–output analysis. The analysis may also be seen as a contribution to the general discussion on the environmental impact of the service sector as it shows evidence against the idea that a growth in the relative importance of the service sector implies a step toward a dematerialized economy.

From the analysis undertaken we could highlight the different roles played by the different service subsectors. Transport services appear to be the main emitter activities in terms of the emissions directly generated in the production of the service sector. The analysis shows that these services are demanded by the other productive activities to a greater extent than their own final demand and, therefore, the production sold to other sectors is more responsible for their emissions than their final demand. However, for the remaining subsectors, direct and indirect emissions associated with their final demand are much more important. This is due to the strong pull effect of services on the other productive activities of the economy. In this respect, an outstanding role is played by Wholesale and retail trade, and repair of vehicles and goods, Hotels and restaurants, Real estate, renting and business services, and Public Administration services. These subsectors usually receive scarce attention in policies aimed at controlling CO_2 emissions, but are highly responsible for the major increase in emissions experienced in recent years.

As regards the different components in which we have decomposed the emissions of the service subsystem, we should highlight the importance of the spill over component. This component mainly corresponds to emissions generated by the consumption of gas and electricity, and to a much lesser extent of petrol products and coal. Apart from transport services, this component is much higher than the emissions generated by the production of services for other sectors. The service sector is therefore more responsible for the level of total emissions than what is usually assigned to it a priori.

In any case, the results of our work refute the idea that a services economy is necessarily a less polluting economy. Although industrial productive processes are more directly linked to energy consumption, the final responsibility of their emissions rests on the sectors that demand their production. As has been demonstrated, some services are largely responsible for the emissions generated in the production of other sectors. Wholesale and retail trade, and repair of vehicles and goods, Hotels and restaurants, and Real estate, renting and business activities are remarkable cases. A policy designed to control and mitigate emissions should consider the importance of the consumption of energy, and the emissions needed to facilitate these sectors' production.

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Table 1. Direct emissions generated by the service sector production, direct emissions of the service sector production caused by sales to other sectors, and total (direct and indirect) emissions caused by the service sector demand

	Direct CO_2 emission of the service sector production		Direct CO_2 emissions caused by sales to other sectors		Total CO_2 emissions caused by the service sector demand	
Subsectors of the service sector	**Kt**	**% total emission**	**Kt**	**% total emission**	**Kt**	**% total emission**
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	5,236.0	2.1	847.0	0.3	18,317.0	7.4
Hotels and restaurants	2,780.0	1.1	54.1	0.0	14,264.0	5.7
Land transport; transport via pipelines	19,477.0	7.8	6,969.3	2.8	10,586.5	4.3
Water transport	2,739.0	1.1	484.1	0.2	2,230.1	0.9
Air transport	7,404.0	3.0	758.2	0.3	6,331.8	2.5
Supporting and auxiliary transport activities; activities of travel agencies	1,553.0	0.6	482.2	0.2	2,529.3	1.0
Post and telecommunications	232.0	0.1	42.5	0.0	1,719.3	0.7
Financial intermediation	208.0	0.1	37.5	0.0	1,522.7	0.6
Real estate, renting and business activities	567.0	0.2	101.2	0.0	9,870.7	4.0
Education	743.0	0.3	17.4	0.0	3,331.1	1.3
Health and social work	542.0	0.2	8.4	0.0	4,482.5	1.8
Other community, social and personal service activities	915.0	0.4	35.1	0.0	5,272.9	2.1
Public administration and defence; compulsory social security	1,004.0	0.4	0.0	0.0	7,142.2	2.9
Total service sector	43,400.0	17.5	9,837.0	4.0	87,600.0	35.2

Table 2. Decomposition of the CO_2 emissions of the service sector into different components (kt.)

Subsectors of the service sector	Own comp.	Feed-back comp.	Spill over comp.	Internal comp.	Demand volume comp.	Total (direct and indirect) emission	% of service sector emission
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	224.5	254.9	12,164.2	2,064.8	3,608.6	18,317.0	20.9
Hotels and restaurants	35.1	598.5	10,562.1	483.5	2,584.8	14,264.0	16.3
Land transport; transport via pipelines	133.1	40.9	2,296.4	417.3	7,698.7	10,586.5	12.1
Water transport	4.8	6.5	250.8	60.7	1,907.3	2,230.1	2.5
Air transport	90.7	17.8	751.2	83.3	5,388.8	6,331.8	7.2
Supporting and auxiliary transport activities; activities of travel agencies	88.8	36.9	1,141.9	839.8	421.8	2,529.3	2.9
Post and telecommunications	13.8	32.2	1,540.3	56.7	76.3	1,719.3	2.0
Financial intermediation	22.2	33.4	1,224.9	147.4	94.7	1,522.7	1.7
Real estate, renting and business activities	59.2	388.5	8,588.2	542.1	292.6	9,870.7	11.3
Education	5.4	56.0	2,481.7	81.5	706.5	3,331.1	3.8
Health and social work	33.4	104.6	3,532.8	315.5	496.1	4,482.5	5.1
Other community, social and personal service activities	79.9	163.9	3,972.8	349.3	707.0	5,272.9	6.0
Public administration and defence; compulsory social security	13.8	100.3	5,529.6	494.5	1,004.0	7,142.2	8.2
Total service sector	804.7	1,834.5	54,037.1	5,936.5	24,987.2	87,600.0	100.0
% of total CO_2 emissions generated by productive sectors	0.3	0.7	21.7	2.4	10.0	35.2	

Table 3. Percentage distribution of the spill over component

Subsectors of the service sector	Electricity, gas, steam and hot water supply	Manufact. of other non-metallic mineral products	Manufact. of basic metals	Manufact. of coke, refined petroleum products and nuclear fuel	Other sectors	Total service sector
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	17.4	1.7	0.7	1.4	1.3	22.5
Hotels and restaurants	8.1	2.5	0.4	1.5	7.1	19.5
Land transport; transport via pipelines	2.5	0.2	0.1	1.3	0.2	4.2
Water transport	0.2	0.0	0.0	0.2	0.0	0.5
Air transport	0.3	0.0	0.0	1.0	0.1	1.4
Supporting and auxiliary transport activities; activities of travel agencies	1.3	0.2	0.1	0.4	0.2	2.1
Post and telecommunications	2.1	0.4	0.1	0.1	0.2	2.9
Financial intermediation	1.6	0.3	0.0	0.1	0.2	2.3
Real estate, renting and business activities	9.3	3.5	0.6	0.7	1.8	15.9
Education	3.4	0.4	0.1	0.4	0.4	4.6
Health and social work	4.1	0.8	0.1	0.7	0.8	6.5
Other community, social and personal service activities	4.6	0.9	0.2	0.5	1.1	7.4
Public administration and defence; compulsory social security	8.4	0.5	0.2	0.5	0.7	10.2
Total service sector	63.1	11.4	2.5	8.9	14.0	100.0