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Responsibility and trade emission balances: two approaches for the same concept?

Serrano, Mònica[a*] and Dietzenbacher, Erik[b]

[a] *Department of Economic Theory, University of Barcelona*
Av. Diagonal, 690, 08034 Barcelona, Spain
E-mail: monica.serrano@ub.edu

[b] *Faculty of Economics and Business, University of Groningen*
PO Box 800, 9700 AV Groningen, The Netherlands
E-mail: h.w.a.dietzenbacher@rug.nl

* Corresponding author: Phone: (34) 93 402 01 11 Fax: (34) 93 403 90 82

Abstract

This paper defines and compares two concepts to evaluate the international responsibility of one country regarding emissions: the trade emission balance and the responsibility emission balance. We use a multiregional input-output model. First, we show that both approaches yield the same result. Then, we introduce the same technology assumption and we show that under this assumption both balances are equivalent to a third approach, which simply evaluates the emissions embodied in the net exports of the country. However, the application of this third approach should be restricted to make evaluations at aggregate level, i.e. a country, because at sectorial level it yields different results. For the empirical application, we compute the results for Spain in 1995 and 2000, distinguishing nine different gases: the six greenhouse gases regulated by the Kyoto protocol (CO_2, CH_4, N_2O, SF_6, HFC_s, and PFC_s); and three other gases (SO_2, NO_x, and NH_3).

Keywords: international trade, producer and consumer responsibility, atmospheric pollutants, multiregional input-output.

1. Introduction

Through international trade the consumption in one country is linked to emissions generated in other countries. As consequence, the emissions actually generated in one country do not need to be the same as the emissions that are (directly and indirectly) necessary for its consumption. The debate about the consequences of international trade on the environment, although not new, has gained much importance in the last decade due to the Kyoto protocol. This international agreement determines emission ceilings on six specified greenhouse gases for each ratifier country (United Nations, 1997).[1]

These national targets, as well as the official data for monitoring countries' achievements, have been fixed on the basis of emissions generated by domestic production neglecting part of the emissions embodied in international trade. That is, emissions generated by domestic production include emissions embodied in exports but not those embodied in imports. Consequently, it has been argued that open economies that increase exports of intensive pollutant commodities should make a considerable effort to achieve its national target, being suggested that international trade should be considered to establish equitable and feasible reduction targets (Munksgaard and Pedersen, 2001).

This situation leads to the question of how to evaluate the environmental responsibility of one country in global terms; that is, what would be the responsibility of one country regarding the rest of the world? Traditionally, the international responsibility of one country has been approached from two viewpoints. On the one hand, comparing the emissions embodied in exports with those embodied in imports; and on the other hand, confronting the producer and consumer responsibilities.

This paper aims at contributing theoretically and empirically to the international responsibility issue by merging both approaches. We use an environmentally extended multiregional input-output model to define and compare the two concepts, i.e. the trade emission balance and the responsibility emission balance.

[1] The commitment refers to the aggregation of six gases measured in CO_2 equivalent units, i.e. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

First, we show that both approaches yield the same result about the international responsibility of one country. Then, due to the important constraint that supposes to get data regarding the technology of the rest of the world, we assume that the rest of the world has the same technology as the country analyzed. Under this restrictive but empirically necessary assumption, the above result holds and we show that it can be estimated by applying another approach. This third alternative is simpler since it evaluates the emissions embodied in the net exports of the country. However, we should be careful in which context this third approach is going to be used because although it yields the same result at the aggregate level (i.e. country), the conclusions obtained at the sectorial level are completely different. These results are also proved empirically applying the model for the Spanish economy in 1995 and 2000. We compute the results for nine different gases: the six greenhouse gases (CO_2, CH_4, N_2O, SF_6, HFC_s, and PFC_s) and three other gases related to local environmental pressures (SO_2, NO_x, and NH_3). We found that Spain was a 'net exporter' for all gases in both years. The only exception to this was the NH_3 in 2000. Nevertheless, these results have to be interpreted carefully because the implausible but empirically necessary assumption of the same technology.

As shown the comprehensive surveys of Jayadevappa and Chhatre (2000) and Wiedmaan *et al.* (2007), since the 1970's there has been a growing interest on the complex interactions between economic growth, trade, and environment. The first work in analyzing the emissions contained in the international trade of the United States was Walter (1973). However, in the last years there have been an increase of works that compare the emissions associated with exports and imports for different countries such as Germany and United Kingdom (Proops *et al.*, 1993), Japan (Kondo *et al.*, 1998), Denmark (Munksgaard and Perdersen, 2001), Brazil (Machado *et al.*, 2001; Tolmasquim and Machado, 2003), Spain (Sánchez-Chóliz and Duarte, 2004), Italy (Mongelli *et al.*, 2006), India (Mukhopadhyay and Chakrabory, 2005; Dietzenbacher and Mukhopadhyay, 2007), and Turkey (Tunç *et al.*, 2007). Antweiler (1996) calculated an index of pollution terms of trade for 164 different countries.

Although there are methodological differences amongst them, all of these studies analyse relationships between one country and the rest of the world, assuming

that the rest of the world has the same technology as the country analyzed. This assumption is frequently adopted due to the lack of data concerning the 'global' technology of the rest of the world. However, improvements in data availability and quality have made possible, in some cases, to develop and apply more sophisticated models that take different technologies between regions into account. Thus, bilateral trade studies have been carried out between Japan and Canada (Hayami and Nakamura, 2002), Japan and South Korea (Rhee and Chung, 2006), and Japan and the United States (Ackerman *et al.*, 2007). Other works have considered more regions such as Wyckoff and Roop (1994) who estimated the embodied emissions in imports of six OECD countries (Canada, France, Germany, Japan, the United Kingdom, and the United States). Ahmad and Wyckoff (2003) enlarged this study estimating the emissions embodied in international trade of goods of 24 OECD countries. Lenzen *et al.* (2004) calculated the trade balance taking into account five regions (Denmark, Germany, Sweden, Norway and the rest of the world); Nijdam *et al.* (2005) analyzed the impacts of Dutch household consumption considering the Netherlands and three different world regions, and Peters and Hertwich (2006a, 2006b) analyzed the environmental impacts of Norway final demand aggregating all its trading partners into seven regions. However, the principal drawback to this approach is the difficulty of getting the necessary and detailed data on interregional transactions. Moreover, even in these works it is necessary to make some assumption about the technology of the rest of the world when it is considered as a region in the model. Nevertheless, these works are a sign of the importance of considering different technologies when estimating the emissions embodied in trade.

On the other hand, the international responsibility of a country can also be defined from a different perspective. Since the place where the production of goods and services take place do not need to be the same as the place where the consumption of these products occurs, we can define the responsibility of a country from two sides: the producer or the consumer standpoint[2] (Proops *et al.*, 1993; Steenge, 1999; Munksgaard

[2] Although the producer and consumer responsibilities are the terminology commonly used in the literature, it is important to advise that the term 'consumer responsibility' might be a little misleading. In the literature this term refers not only to emissions derived from household consumption but it also includes those emissions generated by government spending and gross investment; that is, it refers to

and Pedersen, 2001). The former establishes that any country is responsible for those emissions associated with its domestic production regardless where it is going to be consumed. Whereas the latter determines the country's responsibility depending on its consumption, i.e. a country is responsible for those emissions generated in order to satisfy its domestic final demand regardless where it has been produced. Both concepts have been introduced to evaluate the ecological footprint of different economic agents and countries, opening a methodological debate about the double-counting (Lenzen *et al.*, 2007). Two different solutions have been proposed by Gallego and Lenzen (2005) and Rodrigues *et al.* (2006). Both alternatives assign the quantitative contribution of each agent to the environmental problem; however, the implications for environmental policy that are derived from each one could be different (Rodrigues and Domingos, 2008).

The reminder of the paper proceeds as follows. In Section 2, we develop an environmentally extended multiregional input-output model to define the trade emission balance and the responsibility emission balance. In Section 3, we analyse the empirical results obtained for Spain in 1995 and 2000. Finally, some conclusions are considered in Section 4.

2. Methodology

We consider a world economy consisting of two regions (1 and 2) that may differ in production technology and/or pollution patterns. Country 2 may be taken as the rest of the world. Each region is composed of n sectors, which produce one product that might be used by other sectors as intermediate input (either at home or abroad) or consumed or invested (at home or abroad) as final product by final user categories such as households and the government. The intermediate deliveries from sector i in region r to sector j in region s are denoted by the element z_{ij}^{rs} of the matrix $\mathbf{Z}^{rs}$, with $r, s = 1, 2$, and $i, j = 1, ..., n$. [3] The deliveries from sector i in region r to final users in region s are

domestic final demand. In order to avoid this confusion in this paper we will use the term 'final user responsibility' to refer to 'consumer responsibility'.

[3] Matrices are indicated by bold, upright capital letters; vectors by bold, upright lower case letters; and scalars by italicised lower case letters. Vectors are columns by definition, so that row vectors are obtained by transposition, indicated by a prime. A diagonal matrix with the elements of any vector on its main diagonal and all other entries equal to zero is indicated by a circumflex.

given by the element y_i^{rs} of the vector $\mathbf{y}^{rs}$. The output in sector *i* in region *r* is given by x_i^r of the vector $\mathbf{x}^r$.The accounting equations become

$$\begin{pmatrix}\mathbf{x}^1\\ \mathbf{x}^2\end{pmatrix}=\begin{bmatrix}\mathbf{Z}^{11} & \mathbf{Z}^{12}\\ \mathbf{Z}^{21} & \mathbf{Z}^{22}\end{bmatrix}\begin{pmatrix}\mathbf{i}\\ \mathbf{i}\end{pmatrix}+\begin{pmatrix}\mathbf{y}^{11}+\mathbf{y}^{12}\\ \mathbf{y}^{21}+\mathbf{y}^{22}\end{pmatrix} \tag{1}$$

where **i** is the column summation vector (i.e. entirely consisting of ones) of appropriate length. We can rewrite (1) as

$$\mathbf{x}=\mathbf{Z}\mathbf{i}+\mathbf{y} \tag{2}$$

Notice that the matrices $\mathbf{Z}^{11}$ and $\mathbf{Z}^{22}$ indicate the intra-regional transactions (i.e. within the region), whereas $\mathbf{Z}^{12}$ and $\mathbf{Z}^{21}$ indicate the inter-regional transactions with imports of products that are used as inputs. Similarly, $\mathbf{y}^{11}$ and $\mathbf{y}^{22}$ represent the domestic final demands and $\mathbf{y}^{12}$ and $\mathbf{y}^{21}$ give the imports by final users (i.e. households and the government).

The input coefficients are obtained from $\mathbf{A}=\mathbf{Z}\hat{\mathbf{x}}^{-1}$ which can be partitioned in the same fashion as **Z**. We thus have $\mathbf{A}^{rs}=\mathbf{Z}^{rs}(\hat{\mathbf{x}}^s)^{-1}$ or $a_{ij}^{rs}=z_{ij}^{rs}/x_j^s$. Note that $\mathbf{A}^{11}$ and $\mathbf{A}^{22}$ are matrices of domestic input coefficients, and $\mathbf{Z}^{12}$ and $\mathbf{Z}^{21}$ are coefficient matrices for the imported inputs. Equation (2) can now be written as $\mathbf{x}=\mathbf{A}\mathbf{x}+\mathbf{y}$, or in its partitioned form as

$$\begin{pmatrix}\mathbf{x}^1\\ \mathbf{x}^2\end{pmatrix}=\begin{bmatrix}\mathbf{A}^{11} & \mathbf{A}^{12}\\ \mathbf{A}^{21} & \mathbf{A}^{22}\end{bmatrix}\begin{pmatrix}\mathbf{x}^1\\ \mathbf{x}^2\end{pmatrix}+\begin{pmatrix}\mathbf{y}^{11}+\mathbf{y}^{12}\\ \mathbf{y}^{21}+\mathbf{y}^{22}\end{pmatrix} \tag{3}$$

The solution of $\mathbf{x}=\mathbf{A}\mathbf{x}+\mathbf{y}$ is given by $\mathbf{x}=(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}=\mathbf{L}\mathbf{y}$, where $\mathbf{L}\equiv(\mathbf{I}-\mathbf{A})^{-1}$ indicates the Leontief inverse. In partitioned form, this reads as follows.

$$\begin{pmatrix}\mathbf{x}^1\\ \mathbf{x}^2\end{pmatrix}=\begin{bmatrix}\mathbf{L}^{11} & \mathbf{L}^{12}\\ \mathbf{L}^{21} & \mathbf{L}^{22}\end{bmatrix}\begin{pmatrix}\mathbf{y}^{11}+\mathbf{y}^{12}\\ \mathbf{y}^{21}+\mathbf{y}^{22}\end{pmatrix} \tag{4}$$

In order to estimate emissions associated with the production in each region, we define the matrix of atmospheric emission coefficients $\mathbf{W}^r$, whose element w_{kj}^r indicates the domestic emission of pollutant *k* per unit of industry *j*'s output in region *r*. The emissions (or pollution) generated in each region are given by

$$\begin{pmatrix}\mathbf{p}^1\\ \mathbf{p}^2\end{pmatrix}=\begin{pmatrix}\mathbf{W}^1\mathbf{x}^1\\ \mathbf{W}^2\mathbf{x}^2\end{pmatrix}=\begin{bmatrix}\mathbf{W}^1\mathbf{L}^{11} & \mathbf{W}^1\mathbf{L}^{12}\\ \mathbf{W}^2\mathbf{L}^{21} & \mathbf{W}^2\mathbf{L}^{22}\end{bmatrix}\begin{pmatrix}\mathbf{y}^{11}+\mathbf{y}^{12}\\ \mathbf{y}^{21}+\mathbf{y}^{22}\end{pmatrix}$$
$$=\begin{bmatrix}\mathbf{P}^{11} & \mathbf{P}^{12}\\ \mathbf{P}^{21} & \mathbf{P}^{22}\end{bmatrix}\begin{pmatrix}\mathbf{y}^{11}+\mathbf{y}^{12}\\ \mathbf{y}^{21}+\mathbf{y}^{22}\end{pmatrix} \qquad (5)$$

Note that element p_{kj}^{rs} of matrix $\mathbf{P}^{rs}$ gives the total amount of (extra) emissions of pollutant *k* in region *r*, due to the delivery of one (extra) unit of product *j* from region *s* to its final users (either at home or abroad).

2.1 Trade and responsibility emission balances

Analyzing emissions embodied in international trade requires the comparison of the emissions embodied in exports with the emissions embodied in imports. For region 1, the emissions embodied in its exports comprise three components. First, the emissions generated inside region 1 to meet the demand $\mathbf{y}^{12}$ by foreign final users. Second, the emissions generated in region 2 to produce the inputs that region 1 requires to produce $\mathbf{y}^{12}$. Third, the emissions generated in region 1 for producing the inputs that enter the production process in region 2 for satisfying its final users (both domestic and foreign). This yields for the emissions in the exports of region 1

$$em\ exp\ 1 = \mathbf{P}^{11}\mathbf{y}^{12}+\mathbf{P}^{21}\mathbf{y}^{12}+\mathbf{P}^{12}(\mathbf{y}^{21}+\mathbf{y}^{22}) \qquad (6)$$

In the same fashion, we have for the emissions embodied in region 1's imports

$$em\ imp\ 1 = \mathbf{P}^{22}\mathbf{y}^{21}+\mathbf{P}^{12}\mathbf{y}^{21}+\mathbf{P}^{21}(\mathbf{y}^{11}+\mathbf{y}^{12}) \qquad (7)$$

The trade emission balance for region 1 (i.e. $\mathbf{teb}^1$) is defined as the difference between the emissions embodied in exports and those embodied in imports. That is

$$\mathbf{teb}^1 = \mathbf{P}^{11}\mathbf{y}^{12} + \mathbf{P}^{12}\mathbf{y}^{22} - \mathbf{P}^{22}\mathbf{y}^{21} - \mathbf{P}^{21}\mathbf{y}^{11} \qquad (8)$$

Notice that the trade emission balance for region 2 may be obtained in the same way. Alternatively, $\mathbf{teb}^2$ may be obtained from replacing in equation (8) all indexes 1 by 2 and vice versa. In this two-region case, we then have $\mathbf{teb}^2 = -\mathbf{teb}^1$, or $\mathbf{teb}^1 + \mathbf{teb}^2 = 0$.

The international responsibility of a region is defined from a different perspective. That is, by comparing the emissions produced inside the region with the emissions required by its domestic final users. As mentioned in the introduction, the producer's responsibility in region 1 covers all emissions generated by the region's production, regardless where it will be consumed, i.e. inside or outside the region. That is

$$em\ prod\ 1 = \mathbf{P}^{11}(\mathbf{y}^{11} + \mathbf{y}^{12}) + \mathbf{P}^{12}(\mathbf{y}^{21} + \mathbf{y}^{22}) \qquad (9)$$

However, from the viewpoint of the final users in region 1,[4] the region is responsible for all emissions that are caused by their 'consumption', no matter where the emissions have been generated. Included are the emissions generated: in region 1 to produce domestic final demands in region 1; the emissions in region 2 to produce the inputs that are imported by region to produce their domestic final demands; the emissions generated in region 2 to produce the foreign final demands (i.e. the exports to final users in region 1); and the emissions generated in region 1 to produce the inputs that are imported by region 2 for producing the exports to final users in region 1. This yields

$$em\ finus\ 1 = (\mathbf{P}^{11} + \mathbf{P}^{21})\mathbf{y}^{11} + (\mathbf{P}^{12} + \mathbf{P}^{22})\mathbf{y}^{21} \qquad (10)$$

[4] It is worth to recall that in the literature it is widely extended the use of the term 'consumer responsibility' instead of 'final user responsibility'; however, to avoid some confusion we prefer to use the latter (see footnote 2).

The responsibility emission balance for region 1 (i.e. $\mathbf{reb}^1$) is defined as the difference between the emissions due to the producer responsibility and the final user responsibility. That is, equation (9) minus equation (10). It is readily seen that this yields equations (8), which proves that $\mathbf{teb}^1 = \mathbf{reb}^1$.

Although the balances have been derived from different definitions, they yield the same expression and hence they can be interpreted in the same way. Therefore, if the balances have a positive sign it implies that the emissions embodied in exports are higher than those embodied in imports, i.e. the region is a "net importer" of emissions. Alternatively, because official data usually list emissions generated by domestic production, this region would actually be less responsible for the environmental pollution than is reported. That is, the producer responsibility is larger than the final user responsibility.[5]

The analysis in this section can be extended to the multi-region case and the results remain the same. The only difficulty is that the equality $\mathbf{teb}^2 = -\mathbf{teb}^1$ for the two-region case does not hold for the multi-region case. Appendix A gives the results for the three-region case and shows 'consistency' of the balances in the sense that $\mathbf{teb}^1 + \mathbf{teb}^2 + \mathbf{teb}^3 = 0$.

2.2 Special case: a small country using the same technology

Bearing the empirical analysis for Spain in mind, we discuss in this subsection the special case of a small country. Using the model of the previous subsection, the country is region 1 and the rest of the world is region 2. The exports of the country are given by the matrix $\mathbf{Z}^{12}$ which will be non-zero. However, the exports will typically be negligible when compared to the rest of the world's outputs. Therefore it seems plausible to assume that $\mathbf{A}^{12} = 0$.

The second assumption that we will make is quite common in the literature. Although technology will differ across countries, actual data for the rest of the world are typically lacking. Therefore it is assumed that the technology and the emission

[5] The responsibility and trade emission balances can also be interpreted as an environmental opportunity cost or profit, depending on whether the sign is positive or negative, respectively.

intensities are the same for the country and the rest of the world. Note that the technology is given by the structure of the inputs, no matter whether domestically produced or imported. That is, assuming the same technology implies $\mathbf{A}^{11} + \mathbf{A}^{21} = \mathbf{A}^{22} + \mathbf{A}^{12}$ (together with the assumption that $\mathbf{A}^{12} = 0$, this yields $\mathbf{A}^{11} + \mathbf{A}^{21} = \mathbf{A}^{22}$) and assuming the same emission intensities implies $\mathbf{W}^1 = \mathbf{W}^2$.

We can now simplify the notation, so that equation (3) becomes

$$\begin{pmatrix} \mathbf{x}^1 \\ \mathbf{x}^2 \end{pmatrix} = \begin{bmatrix} \mathbf{A} & 0 \\ \mathbf{M} & \mathbf{A}+\mathbf{M} \end{bmatrix} \begin{pmatrix} \mathbf{x}^1 \\ \mathbf{x}^2 \end{pmatrix} + \begin{pmatrix} \mathbf{y}^{11} + \mathbf{y}^{12} \\ \mathbf{y}^{21} + \mathbf{y}^{22} \end{pmatrix} \tag{11}$$

Instead of equation (5) we now have

$$\begin{pmatrix} \mathbf{p}^1 \\ \mathbf{p}^2 \end{pmatrix} = \begin{bmatrix} \mathbf{W}(\mathbf{I}-\mathbf{A})^{-1} & 0 \\ \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{M}(\mathbf{I}-\mathbf{A})^{-1} & \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1} \end{bmatrix} \begin{pmatrix} \mathbf{y}^{11} + \mathbf{y}^{12} \\ \mathbf{y}^{21} + \mathbf{y}^{22} \end{pmatrix} \tag{12}$$

The emission balance (no matter whether trade or responsibility) in (8) now becomes

$$\begin{aligned} \mathbf{eb}^1 &= \mathbf{W}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}^{12} - \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{y}^{21} \\ &\quad - \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}^{11} \end{aligned} \tag{13}$$

Usually, a much simpler expression is used when the assumption of the same technology is adopted. That is, the emissions corresponding to the trade balance (i.e. exports minus imports). So, the alternative expression is given by

$$\overline{\mathbf{eb}}^1 = \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}(\mathbf{exp}^1 - \mathbf{imp}^1) \tag{14}$$

where $\mathbf{exp}^1 = \mathbf{y}^{12}$ gives the vector of exports of country 1 and $\mathbf{imp}^1$ the vector of total imports. Note that it follows from (11) that $\mathbf{imp}^1 = \mathbf{M}\mathbf{x}^1 + \mathbf{y}^{21} = \mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}(\mathbf{y}^{11} + \mathbf{y}^{12}) + \mathbf{y}^{21}$. The alternative in equation (14) has one major advantage in terms of data requirements. Observe that the application of (13)

requires that the input-output data are such that the domestically produced inputs are separated from the imported inputs. Such data are not always available and only the sum of the two matrices (also known as the technical input matrix) is available. Appendix B shows that the two expressions in (13) and (14) are the same, so that also in the case where only a technical input matrix is available we arrive at the same answer.

However, this equivalence does not hold when analyzing sectorial emission balances. Let $\hat{\mathbf{y}}^{12}$, $\hat{\mathbf{y}}^{21}$, $\hat{\mathbf{y}}^{11}$, $\widehat{\mathbf{exp}}^{1}$, and $\widehat{\mathbf{imp}}^{1}$ be diagonal matrices of $\mathbf{y}^{12}$, $\mathbf{y}^{21}$, $\mathbf{y}^{11}$, $\mathbf{exp}^{1}$, and $\mathbf{imp}^{1}$ vectors; the emission balances by sectors derived from expressions (15) and (16) would be respectively:

$$\mathbf{EB}^{1} = \mathbf{W}(\mathbf{I}-\mathbf{A})^{-1}\hat{\mathbf{y}}^{12} - \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\hat{\mathbf{y}}^{21} - \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}\hat{\mathbf{y}}^{11} \quad (15)$$

$$\overline{\mathbf{EB}}^{1} = \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}(\widehat{\mathbf{exp}}^{1} - \widehat{\mathbf{imp}}^{1}) \quad (16)$$

Emission balances of each sector calculated by expression (15) do not fit in with those obtained using its counterpart expression (16), although the total were the same in both cases.

3. Empirical results

The basic data source of this paper is the 1995 and 2000 Spanish supply and use tables and Spanish environmental accounts for air emissions (INE 2005, 2006). However, to compute the model presented above it is required some data preparation. Appendix C shows the Spanish data set and the assumptions and procedures adopted in this paper.

Tables 1 and 2 present the first main result. That is, the international responsibility about emissions of any region can be calculated through either the trade emission balance or the responsibility emission balance. From both approaches we get the same result (see columns 3 and 6 in both tables). Table 1 shows the Spanish trade emission balance for 1995 and 2000. Columns 1 and 4 gather emissions embodied in

exports, whereas columns 2 and 5 do for emissions embodied in imports. As we can see emissions embodied in Spanish imports are higher than emissions embodied in Spanish exports and hence, Spain has a negative trade emission balance for all gases in both years. The only exception to this is the case of NH_3 in 2000. So, Spain would have been 'exporting' pollution to other countries if the rest of the world had produced commodities using the same technology as Spain.

Table 1

However, the international responsibility of Spain can also be defined by comparing emissions produced in Spain with those required by its domestic final demand. Columns 3 and 6 of Table 2 show the responsibility emission balance for Spain in 1995 and 2000. These columns are the difference between the producer responsibility (columns 1 and 4) and the final user responsibility (columns 2 and 5). The former is lower almost in all gases in both years. Again the only exception is the NH_3 in 2000. This result reveals that Spain's responsibility as a final user is greater than as a producer. Since most of official statistics such as NAMEA data are reported from the producer perspective, these results would indicate that assuming that the rest of the world and Spain use the same technology, the official reports may be underestimating the responsibility of Spanish domestic final demand.

Table 2

The implications of these results vary depending of the kind of pollutant considered. In the case of local and regional gases, i.e. SO_2, NO_x, and NH_3, it would mean that Spain is shifting environmental costs to other countries. However, in the case of global pollutants as the greenhouse gases it would mean that the responsibility of the country is greater than it could seem. If we focus on the last column of both tables, we can see that from 1995 and 2000 the international responsibility of Spain increased considerably in the synthetic greenhouse gases and in two of the three gases related to energy products, i.e. CO_2 and NO_x. For SO_2 the increase was much more moderate. On the contrary, for those gases connected with agricultural and food activities, i.e. CH_4, N_2O, and NH_3, the evolution of the international responsibilities were the opposite; causing a shift of responsibility in NH_3.

3.1 Results by sectors

The second main result of this work is regarding the assumption about the same technology. In Section 2 we stated that under this assumption the emission balances at aggregate level (i.e. a country) can be calculated by applying either expression (13) or the simpler expression (14) used by other studies. However, when we calculate the emission balances by sectors, the counterpart expressions (i.e. expressions (15) and (16)) lead to different conclusions. We present these results for 1995 in Tables 3, 4, 5, and 6; the results for 2000 are presented in Appendix D.

Table 3 shows the emission balance by sectors computed by expression (15), and Table 4 shows the results obtained with expression (16). As expected, the total row in both tables coincides with the emission balances in Tables 1 and 2; however, the emission balance of each sector differs completely. In fact, each expression (each Table) answers different research questions. Whereas expression (15) (Table 3) takes into account not only how much product each sector has imported, but also other imported inputs that each sector needs to produce its characteristic product, expression (16) (Table 4) only considers how much product of each sector have been exported and imported. Hence, if the purpose is to analyze the responsibility of a country, expression (15) is clearly preferable.

Table 3

Table 4

Sector 44 ‘Health and social work’ illustrates the difference between both expressions. Looking at the two first columns of Tables 3 and 4 we see that logically in 1995 Spain neither exported nor imported any ‘health services’; however, from Table 3 we realize that its emission balances were negative for all gases. The reason is that this sector used some inputs produced abroad such as chemicals products (sector 16) or medical and precision instruments (sector 25), although the production of this sector was exclusively produced and consumed in Spain.

In order to illustrate the importance of choosing the appropriate expression to calculate emission balances by sectors, we have selected the key sectors for each gas

according to both expressions. We only show those sectors whose emission balances represent more than 10% of the total emission balance of each gas. According to expression (15) (Table 5), we find that the main sectors in 1995 to explain the emission balances of CO_2, SO_2, and NO_x were 'Construction', 'Manufacture of food products, beverages, and tobacco', and 'Hotels and restaurants'. Regarding CH_4, N_2O, and NH_3, the sectors more connected with the transformation and distribution of food products ('Manufacture of food products, beverages, and tobacco' and 'Hotels and restaurants') explained together more than 50% of the total emission balances for each gas[6]. Finally, concerning synthetic greenhouse gases 'Construction', 'Health and social work' and 'Manufacture of food products, beverages, and tobacco' were selected as the key sectors in 1995.

Table 5

However, the conclusions from expression (16) are quite different. In Table 6 we can see that for the gases related to energy products, i.e. CO_2, SO_2, and NO_x, the key sectors would have been 'Extraction of crude petroleum, natural gas; uranium and thorium ores' and 'Manufacture of chemicals and chemicals products'; for CH_4 'Manufacture of food products, beverages, and tobacco', 'Extraction of crude petroleum, natural gas; uranium and thorium ores', and 'Mining of coal and lignite; extraction of peat'; for N_2O 'Manufacture of chemicals and chemicals products' and 'Manufacture of food products, beverages, and tobacco'; and for NH_3 'Agriculture, hunting, and related services activities'. Finally, for the synthetic greenhouse gases the key sector would have been only 'Manufacture of chemicals and chemicals products'.

Table 6

4. Conclusions

In this paper we defined and compared two concepts to evaluate the international responsibility of the emissions generated by one country. We defined the responsibility emission balance as the difference between the responsibility of one country as a producer and its responsibility as a consumer or final user; and the trade emission

[6] 'Manufacture of food products, beverages and tobacco' and 'Hotels and restaurants' sectors explained the 64% of

balance as the difference between the emissions embodied in one country's exports and imports. Both emission balances are equivalent in the sense they yield the same result. So, if the balances are negative it indicates that the country is 'exporting' pollution and hence it would more responsible; if the balances are positive the meaning is the opposite, the country is 'importing' pollution and it would be less responsible. The implications of these results vary depending of the kind of pollutant considered. For local and regional gases such as SO_s, NO_x, and NH_3 it means that the country is shifting or displacing environmental costs to other territories. However, for global pollutants such as greenhouse gases it means that the responsibility of the country on global environmental pressures is greater than it could seem from the official statistics, which are based on the producer responsibility standpoint.

Moreover, due to the constraint derived from getting data about the technology and emission patterns of the rest of the world we imposed the restrictive assumption that the rest of the world uses the same technology as the country analyzed. Under this assumption, we showed that the above emission balances are equivalent to evaluate the emissions embodied in the net exports of the country. This third approach has been used in the literature; however, its application should be restricted to evaluate responsibilities at the aggregate level, let say a country, because at the sectorial level this third approach leads to misleading results.

We carried out an empirical application for the Spanish economy for two years (1995 and 2000) and for nine different gases: the six greenhouse gases (CO_2, CH_4, N_2O, SF_6, HFC_s, and PFC_s) and three other gases (SO_2, NO_x, and NH_3). The results indicate that Spain got environmental benefits from international trade because if it had produced inside the country all the products required by its final demand the Spanish emissions would have been higher. We found that Spain was a 'net exporter' of emissions for all the nine gases considered in both years. The only exception to this was the case of NH_3 in 2000. That is, Spain would have been more responsible for global environmental problems that the official statistics reported and it would have also displaced environmental problems to other countries. However, the results presented have to be interpreted carefully because the implausible but empirically necessary

total emission balances of CH_4, the 55% of N_2O, and the 76% of NH_3.

assumption of the same technology assumption. Assuming the rest of the world produced goods and services following the same 'production recipes' as Spain implies that we have estimated, in fact, the emissions actually generated by the country if it had decided to produce all imported products by itself, i.e. they were the emissions avoided by Spain because it purchases some products abroad.

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Appendix A. The three-region case

Equations (1), (3) and (5) now read as follows

$$\begin{pmatrix}\mathbf{x}^1\\ \mathbf{x}^2\\ \mathbf{x}^3\end{pmatrix}=\begin{bmatrix}\mathbf{Z}^{11} & \mathbf{Z}^{12} & \mathbf{Z}^{13}\\ \mathbf{Z}^{21} & \mathbf{Z}^{22} & \mathbf{Z}^{23}\\ \mathbf{Z}^{31} & \mathbf{Z}^{32} & \mathbf{Z}^{33}\end{bmatrix}\begin{pmatrix}\mathbf{i}\\ \mathbf{i}\\ \mathbf{i}\end{pmatrix}+\begin{pmatrix}\mathbf{y}^{11}+\mathbf{y}^{12}+\mathbf{y}^{13}\\ \mathbf{y}^{21}+\mathbf{y}^{22}+\mathbf{y}^{23}\\ \mathbf{y}^{31}+\mathbf{y}^{32}+\mathbf{y}^{33}\end{pmatrix} \tag{A1}$$

$$\begin{pmatrix}\mathbf{x}^1\\ \mathbf{x}^2\\ \mathbf{x}^3\end{pmatrix}=\begin{bmatrix}\mathbf{A}^{11} & \mathbf{A}^{12} & \mathbf{A}^{13}\\ \mathbf{A}^{21} & \mathbf{A}^{22} & \mathbf{A}^{23}\\ \mathbf{A}^{31} & \mathbf{A}^{32} & \mathbf{A}^{33}\end{bmatrix}\begin{pmatrix}\mathbf{x}^1\\ \mathbf{x}^2\\ \mathbf{x}^3\end{pmatrix}+\begin{pmatrix}\mathbf{y}^{11}+\mathbf{y}^{12}+\mathbf{y}^{13}\\ \mathbf{y}^{21}+\mathbf{y}^{22}+\mathbf{y}^{23}\\ \mathbf{y}^{31}+\mathbf{y}^{32}+\mathbf{y}^{33}\end{pmatrix} \tag{A2}$$

$$\begin{pmatrix}\mathbf{p}^1\\ \mathbf{p}^2\\ \mathbf{p}^3\end{pmatrix}=\begin{bmatrix}\mathbf{P}^{11} & \mathbf{P}^{12} & \mathbf{P}^{13}\\ \mathbf{P}^{21} & \mathbf{P}^{22} & \mathbf{P}^{23}\\ \mathbf{P}^{31} & \mathbf{P}^{32} & \mathbf{P}^{33}\end{bmatrix}\begin{pmatrix}\mathbf{y}^{11}+\mathbf{y}^{12}+\mathbf{y}^{13}\\ \mathbf{y}^{21}+\mathbf{y}^{22}+\mathbf{y}^{23}\\ \mathbf{y}^{31}+\mathbf{y}^{32}+\mathbf{y}^{33}\end{pmatrix} \tag{A3}$$

The emissions in the exports and imports of region 1 are given by

$$em\ exp\ 1 =$$
$$(\mathbf{P}^{11}+\mathbf{P}^{21}+\mathbf{P}^{31})(\mathbf{y}^{12}+\mathbf{y}^{13})+\mathbf{P}^{12}(\mathbf{y}^{21}+\mathbf{y}^{22}+\mathbf{y}^{23})+\mathbf{P}^{13}(\mathbf{y}^{31}+\mathbf{y}^{32}+\mathbf{y}^{33})$$

$$em\ imp\ 1 =$$
$$(\mathbf{P}^{12}+\mathbf{P}^{22}+\mathbf{P}^{32})\mathbf{y}^{21}+(\mathbf{P}^{13}+\mathbf{P}^{23}+\mathbf{P}^{33})\mathbf{y}^{31}+(\mathbf{P}^{21}+\mathbf{P}^{31})(\mathbf{y}^{11}+\mathbf{y}^{12}+\mathbf{y}^{13})$$

Their difference gives the trade emission balance:

$$\begin{aligned}\mathbf{teb}^1 &= \mathbf{P}^{11}(\mathbf{y}^{12}+\mathbf{y}^{13})-(\mathbf{P}^{21}+\mathbf{P}^{31})\mathbf{y}^{11}+\mathbf{P}^{12}(\mathbf{y}^{22}+\mathbf{y}^{23})-(\mathbf{P}^{22}+\mathbf{P}^{32})\mathbf{y}^{21}\\ &\quad+\mathbf{P}^{13}(\mathbf{y}^{32}+\mathbf{y}^{33})-(\mathbf{P}^{23}+\mathbf{P}^{33})\mathbf{y}^{31}\end{aligned} \tag{A4}$$

The producer and final user responsibility are given by

em prod 1 =

$$\mathbf{P}^{11}(\mathbf{y}^{11}+\mathbf{y}^{12}+\mathbf{y}^{13})+\mathbf{P}^{12}(\mathbf{y}^{21}+\mathbf{y}^{22}+\mathbf{y}^{23})+\mathbf{P}^{13}(\mathbf{y}^{31}+\mathbf{y}^{32}+\mathbf{y}^{33})$$

em finus 1 =

$$(\mathbf{P}^{11}+\mathbf{P}^{21}+\mathbf{P}^{31})\mathbf{y}^{11}+(\mathbf{P}^{12}+\mathbf{P}^{22}+\mathbf{P}^{32})\mathbf{y}^{21}+(\mathbf{P}^{13}+\mathbf{P}^{23}+\mathbf{P}^{33})\mathbf{y}^{31}$$

The responsibility emission balance $\mathbf{reb}^1$ is obtained from subtracting these two equations from each other. This yields (A4) again, which shows $\mathbf{teb}^1 = \mathbf{reb}^1$.

In the same way, the balances for regions 2 and 3 may be derived. They read as follows.

$$\begin{aligned}\mathbf{teb}^2 = {} & \mathbf{P}^{21}(\mathbf{y}^{11}+\mathbf{y}^{13})-(\mathbf{P}^{11}+\mathbf{P}^{31})\mathbf{y}^{12}+\mathbf{P}^{22}(\mathbf{y}^{21}+\mathbf{y}^{23})-(\mathbf{P}^{12}+\mathbf{P}^{32})\mathbf{y}^{22} \\ & +\mathbf{P}^{23}(\mathbf{y}^{31}+\mathbf{y}^{33})-(\mathbf{P}^{13}+\mathbf{P}^{33})\mathbf{y}^{32} \qquad \text{(A5)}\end{aligned}$$

$$\begin{aligned}\mathbf{teb}^3 = {} & \mathbf{P}^{31}(\mathbf{y}^{11}+\mathbf{y}^{12})-(\mathbf{P}^{11}+\mathbf{P}^{21})\mathbf{y}^{13}+\mathbf{P}^{32}(\mathbf{y}^{21}+\mathbf{y}^{22})-(\mathbf{P}^{12}+\mathbf{P}^{22})\mathbf{y}^{23} \\ & +\mathbf{P}^{33}(\mathbf{y}^{31}+\mathbf{y}^{32})-(\mathbf{P}^{13}+\mathbf{P}^{23})\mathbf{y}^{33} \qquad \text{(A6)}\end{aligned}$$

Writing out equations (A4), (A5) and (A6), and adding them yields zero. This shows that $\mathbf{teb}^1+\mathbf{teb}^2+\mathbf{teb}^3=0$.

Appendix B. Equivalence of expressions for the emission balances

Our starting point is equation (13):

$$\mathbf{eb}^1 = \mathbf{W}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}^{12}-\mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{y}^{21}-\mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}^{11}$$

Using the expression for the imports vector $\mathbf{imp}^1 = \mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}(\mathbf{y}^{11}+\mathbf{y}^{12})+\mathbf{y}^{21}$ gives that $\mathbf{y}^{21} = \mathbf{imp}^1 - \mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}(\mathbf{y}^{11}+\mathbf{y}^{12})$. Substituting this into the expression for the emission balance yields

$$\begin{aligned}\mathbf{eb}^1 &= \mathbf{W}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}^{12} - \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}[\mathbf{imp}^1 - \mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}(\mathbf{y}^{11}+\mathbf{y}^{12})] \\ &\quad - \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}^{11} \\ &= [\mathbf{W}(\mathbf{I}-\mathbf{A})^{-1} + \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{M}(\mathbf{I}-\mathbf{A})^{-1}]\mathbf{y}^{12} - \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{imp}^1\end{aligned}$$

Next consider the sum of the two matrices in the bracketed term:

$$\begin{aligned}&\mathbf{W}(\mathbf{I}-\mathbf{A})^{-1} + \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{M}(\mathbf{I}-\mathbf{A})^{-1} \\ &= \mathbf{W}[\mathbf{I} + (\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\mathbf{M}](\mathbf{I}-\mathbf{A})^{-1} \\ &= \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}[(\mathbf{I}-\mathbf{A}-\mathbf{M}) + \mathbf{M}](\mathbf{I}-\mathbf{A})^{-1} = \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}\end{aligned}$$

This yields $\mathbf{eb}^1 = \mathbf{W}(\mathbf{I}-\mathbf{A}-\mathbf{M})^{-1}(\mathbf{y}^{12} - \mathbf{imp}^1)$ and using $\mathbf{y}^{12} = \mathbf{exp}^1$ gives the expression in equation (14).

Appendix C. Spanish data and data preparation

According to the National Accounting Matrix including Environmental Accounts (NAMEA) system, environmental information is compiled consistently with the way economic activities are represented in national accounts (de Haan and Keuning, 1996; Keuning *et al.*, 1999). The Spanish NAMEA for air emissions is organized according to the supply and use table structure. Thus, the economic accounts cover 110 CPA products, 72 NACE sectors plus a fictitious sector 'Financial Intermediation Services Indirectly Measured' (FISIM), and 7 categories of final uses. The Spanish use table offers information about total, domestic, and imported inputs of each sector, i.e. in a matrix format. On the other hand, the environmental accounts gather information about direct emissions produced by 46 NACE sectors and by households. Air emissions are reported in physical units for different pollutants, amongst them the nine gases considered in this work.

Following the NAMEA principles air emissions related to incineration and decomposition of waste in landfills (mainly CO_2 and CH_4) are placed under NACE 90 'Sewage and refuse disposal services, sanitation, and similar services'. However, this sector is aggregated jointly with NACE 91 'Membership organization services', NACE

92 'Recreational, cultural, and sporting services', and NACE 93 'Other services'. Due to the nature of these four sectors, one can logically infer that the most part of CH_4 emissions and also a smaller amount of CO_2 emissions should be generated almost exclusively by NACE 90; however, this information remains hidden because the above aggregation. Consequently, an increase of household expenditures on cultural or sporting services (NACE 92), for instance, should cause an increase of CH_4 emissions even though this sector only emitted a small amount of this gas. The consequences of this example will not be important if CH_4 emissions of the four-aggregated sector were relatively small compared with total CH_4 emissions, which was not the case (28.30% in 1995 and 31.28% in 2000). Therefore, following Keuning *et al.* (1999) we have assumed that all CH_4 emissions generated by this four-aggregated sector correspond to NACE 90 and we have reallocated them to a new category called 'other sources'.

Taking into account this, we have estimated a 46x46 environmentally extended symmetrical input-output table according to the technology industry hypothesis. From which we have estimated the domestic and imported coefficient matrices $\mathbf{A}^1$ and $\mathbf{M}^2$, and the emission coefficient matrix $\mathbf{W}^1$.

Finally, the so-called synthetic greenhouse gases (SF_6, HFCs, and PFCs) and the six greenhouse gases have been aggregated in accordance with the global warming potential (GWP100) of each gas as established by the Intergovernmental Panel on Climate Change (IPCC, 1997). These conversion factors are: 1 for CO_2, 21 for CH_4, 310 for N_2O, and 23,900 for SF_6. For the group of HFCs and PFCs those values oscillate depending on each specific gas between 140 and 11,700 and 6,500 and 9,200, respectively. In this study we have calculated a warm potential for HFCs and PFCs groups based on the weight average of each group, hence the GWP100 for HFCs is 6,812.65 and for PFCs 6,728.51.

Appendix D. Results by sectors for the year 2000

Table D.1

Table D.2

Table D.3

Table D.4

Tables:

Table 1: Trade emission balance, Spain 1995 and 2000

Units: thousand tones and %

	1995			2000			
	Emission embodied in exports	**Emission embodied in imports**	**Trade emission balance**	**Emission embodied in exports**	**Emission embodied in imports**	**Trade emission balance**	**Variation (%)**
	(1)	(2)	(3) = (1-2)	(4)	(5)	(6) = (4-5)	(6-3)/(3)
Greenhouse gases							
CO_2	75443.04	93662.81	**-18219.76**	120623.29	160794.67	**-40171.39**	120.48
CH_4	374.29	474.51	**-100.22**	548.17	591.32	**-43.15**	-56.95
N_2O	24.63	30.23	**-5.60**	36.21	39.74	**-3.53**	-36.88
Synthetic gases*	2722.00	3736.96	**-1014.95**	5342.12	7327.69	**-1985.57**	95.63
Total in CO_2 equivalent	**93661.36**	**116735.86**	**-23074.50**	**148702.21**	**192860.34**	**-44158.14**	**91.37**
Other gases							
SO_2	599.72	722.73	**-123.01**	657.82	804.88	**-147.06**	19.55
NO_x	369.31	483.94	**-114.63**	591.46	830.61	**-239.15**	108.63
NH_3	99.24	115.35	**-16.11**	156.73	150.05	**6.68**	-141.45

Source: own elaboration from 1995 and 2000 Spanish NAMEA.
* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.

Table 2: Responsibility emission balance, Spain 1995 and 2000

Units: thousand tones and %

	1995			2000			
	Producer responsibility	**Final user responsibility**	**Responsibility emission balance**	**Producer responsibility**	**Final user responsibility**	**Responsibility emission balance**	**Variation (%)**
	(1)	(2)	(3) = (1-2)	(4)	(5)	(6) = (4-5)	(6-3)/(3)
Greenhouse gases							
CO_2	203704.00	221923.76	**-18219.76**	238632.00	278803.39	**-40171.39**	120.48
CH_4	1111.98	1212.20	**-100.22**	1251.37	1294.52	**-43.15**	-56.95
N_2O	68.06	73.65	**-5.60**	79.18	82.71	**-3.53**	-36.88
Synthetic gases*	3585.24	4600.19	**-1014.95**	6235.43	8221.00	**-1985.57**	95.63
Total in CO_2 equivalent	**251738.47**	**274812.97**	**-23074.50**	**295691.46**	**339849.60**	**-44158.14**	**91.37**
Other gases							
SO_2	1759.77	1882.78	**-123.01**	1499.86	1646.93	**-147.06**	19.55
NO_x	1051.14	1165.76	**-114.63**	1141.43	1380.58	**-239.15**	108.63
NH_3	303.87	319.98	**-16.11**	383.94	377.27	**6.68**	-141.45

Source: own elaboration from 1995 and 2000 Spanish NAMEA.
* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.

Table 3: Emission balances by sector according expression (15), Spain 1995

Units: million euros and tones

		Total exports 1995	Total imports 1995	Greenhouse gases					Other gases		
				CO_2	CH_4	N_2O	Synthetic gases*	Total in CO_2 equivalent	SO_2	NO_x	NH_3
S1	Agriculture, hunting, and related services activities	4921.01	4711.33	1682919.53	131647.13	6019.62	-18506.97	6295085.08	5234.52	28793.02	37981.99
S2	Forestry, logging, and related services activities	63.43	198.29	18425.97	627.89	29.38	-16.94	40702.13	51.05	404.66	181.55
S3	Fishing	129.06	662.97	-919127.74	-996.85	-75.16	-4779.34	-968139.99	-3335.77	-13326.53	-200.13
S4	Mining of coal and lignite; extraction of peat	0.20	514.14	-3324.26	-2.63	-0.52	-110.99	-3651.05	-25.82	-16.42	-0.85
S5	Extraction of crude petroleum, natural gas; uranium and thorium ores	3.13	5408.22	10797.95	41.77	0.65	24.93	11901.78	39.05	92.50	0.34
S6	Mining of metal ores	54.60	653.96	45525.46	17.93	2.79	438.64	47206.09	162.02	560.45	2.54
S7	Other mining and quarrying	255.23	303.02	214020.75	226.65	15.56	2077.21	225682.64	2050.30	1044.36	16.15
S8	Manufacture of food products, beverages, and tobacco	5180.59	7492.93	-5100829.45	-90254.87	-4661.14	-190705.87	-8631841.41	-35558.93	-37549.59	-25317.13
S9	Manufacture of textile	1717.24	2068.15	-255062.81	-869.93	-185.09	-47666.97	-378375.36	-2070.02	-910.28	-435.37
S10	Manufacture of wearing apparel; dressing, and dyeing of fur	826.37	1744.76	-1618163.69	-8348.12	-620.62	-80589.77	-2066454.61	-14631.95	-7729.47	-2212.86
S11	Tanning and dressing of leather; manufacture of luggage, and footwear	1549.62	888.68	-148976.14	-1812.59	-149.85	-17782.11	-251274.70	-897.88	-1033.67	-682.38
S12	Manufacture of wood and of products of wood and cork, except furniture	480.77	876.37	129187.03	130.36	12.87	390.69	136303.57	936.17	848.19	28.56
S13	Manufacture of pulp, paper, and paper products	1367.40	2705.85	527359.60	1143.74	78.66	3435.65	579199.14	4808.84	2338.68	206.07
S14	Publishing, printing, and reproduction of recorded media	615.00	480.33	-490880.88	-1263.20	-106.17	-16529.97	-566850.14	-4193.78	-2206.10	-242.22
S15	Manufacture of coke, refined petroleum products, and nuclear fuel	1707.97	1782.27	366314.41	-8820.18	131.53	-13283.05	208581.31	29976.91	-14418.00	-79.61
S16	Manufacture of chemicals and chemicals products	6349.48	10879.31	1950899.04	-819.97	1445.71	438434.81	2820283.33	20848.26	3955.82	2202.05
S17	Manufacture of rubber and plastic products	2280.92	2636.36	384586.97	1065.11	-35.95	-22402.96	373406.86	4644.12	1685.10	-45.38
S18	Manufacture of other non-metallic mineral products	2336.29	1108.09	6260393.25	1622.14	310.54	10873.18	6401599.83	32837.48	17598.01	93.28
S19	Manufacture of basic metals	4058.13	5550.10	6334091.37	5441.98	623.44	273156.06	6914796.32	48974.86	17946.99	279.86
S20	Manufacture of fabricated metal products, except machinery and equipment	1807.18	2063.39	-85336.72	-589.54	-38.41	-13519.87	-123144.32	184.35	-292.19	-60.49
S21	Manufacture of machinery and equipment	4497.02	7515.61	-2172275.09	-3221.57	-294.09	-90866.88	-2421963.19	-17240.64	-8358.14	-367.68
S22	Manufacture of office machinery and computers	1030.83	2713.79	-1004923.90	-1305.45	-144.47	-38945.15	-1116069.24	-8219.82	-4045.15	-211.42
S23	Manufacture of electrical machinery and apparatus	2178.45	3091.31	276850.68	-52.11	5.98	18297.17	295906.23	2620.78	1348.34	-14.02
S24	Manufacture of radio, television and communication equipment and apparatus	1760.30	3295.21	-896889.92	-1244.96	-131.12	-36919.57	-1000601.16	-7412.84	-3535.96	-179.77
S25	Manufacture of medical, precision and optical instruments, watches and clocks	646.32	2416.35	-965807.06	-1195.16	-123.28	-33249.07	-1062370.37	-7779.53	-3833.65	-167.96
S26	Manufacture of motor vehicles, trailers, and semi-trailers	16751.56	12784.06	-1163680.84	-3483.85	-355.02	-98326.06	-1445222.89	-6966.33	-5400.11	-656.27
S27	Manufacture of other transport equipment	1647.11	1207.34	-417858.55	-682.48	-75.35	-26052.47	-481600.29	-3065.02	-1505.04	-106.70
S28	Manufacture of furniture	1347.69	1513.90	-1682251.81	-3782.12	-314.39	-70658.22	-1929794.07	-13528.94	-6984.92	-718.34
S29	Recycling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S30	Electricity, gas, steam, and hot water supply	20.39	129.93	-966068.87	-7425.94	-92.06	-10866.00	-1161416.96	-6234.54	-6132.78	-81.46
S31	Collection, purification, and distribution of water	0.00	0.00	-107160.67	-327.05	-16.92	-3720.19	-122995.08	-844.24	-508.07	-26.03
S32	Construction	8.88	1.19	-8007562.72	-13910.47	-1239.08	-289793.73	-8973590.18	-61523.78	-32923.46	-2089.80
S33	Wholesale and retail trade; repair of motor vehicles, and personal goods	4817.21	647.69	-1533331.05	-4988.45	-374.95	-93422.21	-1847744.06	-11487.79	-6510.60	-691.37
S34	Hotels and restaurants	0.00	76.91	-4311767.07	-66208.72	-3340.94	-127323.05	-6865165.88	-29376.48	-33377.53	-18105.04
S35	Land transport; transport via pipelines	1712.34	189.85	250327.55	-278.87	-9.00	-7574.08	234108.56	-1396.44	3612.84	-41.75
S36	Water transport	907.07	21.29	1400001.89	492.51	63.50	1044.52	1431072.75	15698.32	25373.35	113.10
S37	Air transport	1594.23	999.36	1103159.27	-160.22	44.41	-1295.28	1112266.33	2192.44	3378.28	18.66
S38	Supporting and auxiliary transport activities; activities of travel agencies	1222.66	1205.97	210945.94	131.77	8.34	-2781.05	213517.68	1372.61	1443.71	10.24
S39	Post and telecommunications	432.43	298.52	-104227.09	-250.26	-14.29	-2813.06	-116726.33	-618.11	-497.13	-25.17
S40	Financial intermediation	614.75	475.71	-230413.82	-803.72	-42.35	-6815.53	-267235.97	-1163.00	-1245.14	-105.45
S41	Real estate, renting, and business activities	3860.81	5231.80	-1270536.81	-3395.02	-244.75	-52381.92	-1470087.28	-9259.23	-5876.75	-508.67
S42	Public administration and defense; compulsory social security	0.00	0.00	-1534759.24	-4486.03	-273.25	-47086.45	-1760759.25	-11733.02	-7094.50	-666.66
S43	Education	0.00	0.00	-552726.70	-1880.98	-98.53	-14861.85	-637634.00	-4202.50	-2901.04	-249.75
S44	Health and social work	0.00	0.00	-2941871.93	-7093.45	-1056.59	-247983.55	-3666360.03	-25581.33	-12503.04	-2233.97
S45	Other community, social, and personal service activities	240.31	814.65	-899755.94	-2858.85	-276.66	-33495.89	-1079052.97	-7293.77	-4337.29	-718.09
S46	Private households with employed persons	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**80993.97**	**97358.98**	**-18219764.11**	**-100224.61**	**-5596.99**	**-1014953.16**	**-23074501.15**	**-123009.39**	**-114628.27**	**-16107.42**

Source: own elaboration from 1995 Spanish NAMEA.
* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.

Table 4: Emission balances by sector according expression (16), Spain 1995

Units: million euros and tones

		Total exports 1995	Total imports 1995	Greenhouse gases					Other gases		
				CO_2	CH_4	N_2O	Synthetic gases*	Total in CO_2 equivalent	SO_2	NO_x	NH_3
S1	Agriculture, hunting, and related services activities	4921.01	4711.33	156447.61	8179.06	384.12	2535.89	449820.77	763.82	2007.51	2355.28
S2	Forestry, logging, and related services activities	63.43	198.29	-52813.34	-1515.52	-71.68	-387.67	-107246.99	-196.83	-980.34	-434.31
S3	Fishing	129.06	662.97	-1198838.40	-951.26	-80.37	-3313.10	-1247042.07	-3757.54	-18663.43	-207.94
S4	Mining of coal and lignite; extraction of peat	0.20	514.14	-320701.20	-19073.79	-26.78	-3506.39	-733058.44	-3107.61	-1786.49	-27.34
S5	Extraction of crude petroleum, natural gas; uranium and thorium ores	3.13	5408.22	-8480297.12	-32211.89	-547.79	-33354.18	-9359915.61	-32336.05	-71025.89	-350.55
S6	Mining of metal ores	54.60	653.96	-557832.18	-308.29	-40.09	-7283.12	-584017.42	-2236.17	-6397.84	-42.42
S7	Other mining and quarrying	255.23	303.02	-47646.69	-64.54	-4.01	-609.46	-50853.83	-443.77	-233.86	-4.64
S8	Manufacture of food products, beverages, and tobacco	5180.59	7492.93	-1745331.61	-39554.61	-1907.46	-26791.49	-3194083.75	-10355.87	-16718.34	-11222.54
S9	Manufacture of textile	1717.24	2068.15	-286358.30	-1658.11	-111.69	-11999.73	-367803.02	-2705.50	-1391.18	-429.81
S10	Manufacture of wearing apparel; dressing, and dyeing of fur	826.37	1744.76	-501926.92	-2272.30	-157.08	-16030.58	-614371.85	-4604.35	-2416.32	-571.30
S11	Tanning and dressing of leather; manufacture of luggage, and footwear	1549.62	888.68	354445.31	2329.03	122.69	10302.82	451690.53	3128.39	1816.85	495.67
S12	Manufacture of wood and of products of wood and cork, except furniture	480.77	876.37	-228128.76	-682.61	-45.16	-3380.55	-259844.96	-1693.50	-1502.45	-164.02
S13	Manufacture of pulp, paper, and paper products	1367.40	2705.85	-1203782.38	-2765.40	-197.18	-18953.28	-1341933.63	-10713.14	-5379.87	-482.33
S14	Publishing, printing, and reproduction of recorded media	615.00	480.33	80910.02	154.93	13.79	1678.92	90117.98	762.57	357.19	29.52
S15	Manufacture of coke, refined petroleum products, and nuclear fuel	1707.97	1782.27	-214488.86	-321.77	-20.06	-468.16	-227931.53	-2214.14	-933.45	-6.65
S16	Manufacture of chemicals and chemicals products	6349.48	10879.31	-5648299.95	-7545.42	-2638.68	-716122.95	-7340868.38	-53410.06	-19754.46	-4532.17
S17	Manufacture of rubber and plastic products	2280.92	2636.36	-268194.22	-508.12	-71.90	-16673.73	-317826.55	-2668.69	-1038.83	-128.19
S18	Manufacture of other non-metallic mineral products	2336.29	1108.09	3841343.35	1484.20	213.69	13389.02	3952145.02	20775.20	11222.44	107.20
S19	Manufacture of basic metals	4058.13	5550.10	-2915254.98	-3081.31	-301.09	-122056.11	-3195356.67	-22353.25	-9291.30	-183.94
S20	Manufacture of fabricated metal products, except machinery and equipment	1807.18	2063.39	-241660.71	-276.36	-26.28	-8128.77	-263740.41	-2043.12	-925.14	-27.25
S21	Manufacture of machinery and equipment	4497.02	7515.61	-2255187.86	-2505.04	-276.97	-78369.47	-2472024.43	-18631.80	-8559.31	-311.53
S22	Manufacture of office machinery and computers	1030.83	2713.79	-1001043.17	-1168.12	-135.80	-35445.82	-1103117.55	-8162.01	-4030.70	-194.39
S23	Manufacture of electrical machinery and apparatus	2178.45	3091.31	-791368.37	-898.07	-92.06	-38714.12	-877480.89	-6568.76	-3265.85	-107.68
S24	Manufacture of radio, television and communication equipment and apparatus	1760.30	3295.21	-996451.71	-1057.93	-124.10	-30129.22	-1087269.91	-8444.65	-3841.48	-146.20
S25	Manufacture of medical, precision and optical instruments, watches and clocks	646.32	2416.35	-891597.72	-1044.68	-112.18	-29813.03	-978124.82	-7348.30	-3667.57	-157.39
S26	Manufacture of motor vehicles, trailers, and semi-trailers	16751.56	12784.06	3293614.05	4152.21	468.25	126475.87	3652443.81	28726.64	12139.99	638.52
S27	Manufacture of other transport equipment	1647.11	1207.34	316969.72	358.92	43.21	10343.71	348246.65	2645.96	1135.98	55.38
S28	Manufacture of furniture	1347.69	1513.90	-104955.28	-178.71	-16.62	-2967.40	-116827.03	-806.37	-504.49	-36.57
S29	Recycling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S30	Electricity, gas, steam, and hot water supply	20.39	129.93	-515952.90	-670.85	-15.53	-424.39	-535279.05	-7357.69	-2008.98	-4.39
S31	Collection, purification, and distribution of water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S32	Construction	8.88	1.19	5856.13	7.48	0.63	80.42	6287.56	38.26	23.08	1.39
S33	Wholesale and retail trade; repair of motor vehicles, and personal goods	4817.21	647.69	1238977.59	1840.28	157.52	21497.18	1347951.84	10702.69	6053.91	309.03
S34	Hotels and restaurants	0.00	76.91	-28382.10	-385.46	-19.01	-348.83	-42719.70	-218.38	-218.89	-106.94
S35	Land transport; transport via pipelines	1712.34	189.85	987364.30	1534.58	78.72	3936.79	1047929.96	4909.68	7292.16	67.70
S36	Water transport	907.07	21.29	1601637.09	1016.18	92.64	4334.94	1656030.93	17253.49	26463.97	179.73
S37	Air transport	1594.23	999.36	741677.78	532.48	47.49	1770.12	769350.52	2600.56	2955.08	61.45
S38	Supporting and auxiliary transport activities; activities of travel agencies	1222.66	1205.97	7529.42	16.01	0.96	76.81	8241.36	52.71	45.23	2.42
S39	Post and telecommunications	432.43	298.52	19271.20	24.23	1.61	141.88	20420.11	181.15	78.00	2.27
S40	Financial intermediation	614.75	475.71	46826.92	77.78	4.89	375.17	50351.02	481.50	183.83	10.56
S41	Real estate, renting, and business activities	3860.81	5231.80	-260345.53	-386.47	-39.40	-4388.58	-285062.56	-2335.09	-1084.92	-83.95
S42	Public administration and defense; compulsory social security	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S43	Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S44	Health and social work	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S45	Other community, social, and personal service activities	240.31	814.65	-155794.36	-845.33	-148.22	-2232.56	-221728.17	-1319.35	-782.11	-459.11
S46	Private households with employed persons	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**80993.97**	**97358.98**	**-18219764.11**	**-100224.61**	**-5596.99**	**-1014953.16**	**-23074501.15**	**-123009.39**	**-114628.27**	**-16107.42**

Source: own elaboration from 1995 Spanish NAMEA.

* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.

Table 5: Key sectors according expression (15), Spain 1995

CO_2	CH_4	N_2O	Synthetic gases*	Total in CO_2 equivalent
S32 Construction S8 Manufacture of food S34 Hotels and restaurants	S8 Manufacture of food S34 Hotels and restaurants	S8 Manufacture of food S34 Hotels and restaurants	S32 Construction S44 Health and social work S8 Manufacture of food	S32 Construction S8 Manufacture of food S34 Hotels and restaurants

SO_2	NO_x	NH_3
S32 Construction S8 Manufacture of food S34 Hotels and restaurants	S32 Construction S8 Manufacture of food S34 Hotels and restaurants	S8 Manufacture of food S34 Hotels and restaurants

Source: own elaboration from 1995 Spanish NAMEA.
* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.

Table 6: Key sectors according expression (16), Spain 1995

CO_2	CH_4	N_2O	Synthetic gases*	Total in CO_2 equivalent
S5 Extraction of petroleum S16 Manufacture of chemicals	S8 Manufacture of food S5 Extraction of petroleum S4 Mining of coal and lignite	S16 Manufacture of chemicals S8 Manufacture of food	S16 Manufacture of chemicals	S5 Extraction of petroleum S16 Manufacture of chemicals

SO_2	NO_x	NH_3
S16 Manufacture of chemicals S5 Extraction of petroleum	S5 Extraction of petroleum S16 Manufacture of chemicals	S1 Agriculture

Source: own elaboration from 1995 Spanish NAMEA.
* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.

Table D.1: Emission balances by sector according expression (15), Spain 2000

Units: million euros and tones

		Total exports 2000	Total imports 2000	Greenhouse gases					Other gases		
				CO_2	CH_4	N_2O	Synthetic gases*	Total in CO_2 equivalent	SO_2	NO_x	NH_3
S1	Agriculture, hunting, and related services activities	7027.00	4877.60	2589646.84	197174.87	9681.13	-23558.73	9707910.31	4902.17	41111.44	62172.29
S2	Forestry, logging, and related services activities	154.60	498.60	41819.59	1307.23	65.47	104.64	89672.09	80.06	769.22	411.43
S3	Fishing	319.80	764.90	-935863.65	-988.27	-80.00	-7936.20	-989353.05	-2502.09	-12653.55	-227.37
S4	Mining of coal and lignite; extraction of peat	1.40	875.70	-1172.35	48.00	-0.18	-40.28	-259.57	-4.19	-6.00	-0.41
S5	Extraction of crude petroleum, natural gas; uranium and thorium ores	3.40	15513.30	-217130.69	-350.62	-14.81	-688.92	-229773.67	-367.76	-1648.54	-10.72
S6	Mining of metal ores	98.50	1151.80	105951.72	48.89	6.67	1516.53	110562.30	231.18	1244.78	8.03
S7	Other mining and quarrying	503.50	527.10	269878.31	271.33	27.01	7930.09	291880.64	1882.22	1387.28	39.93
S8	Manufacture of food products, beverages, and tobacco	9219.30	10842.80	-5571931.78	-67986.80	-3783.09	-271911.98	-8444325.21	-25708.55	-35098.36	-20447.06
S9	Manufacture of textile	2919.30	3693.80	-271921.06	-481.92	-154.93	-54601.40	-384669.63	-1302.31	-1117.86	-350.97
S10	Manufacture of wearing apparel; dressing, and dyeing of fur	1999.80	3773.30	-2157668.79	-8656.32	-647.93	-164502.65	-2704813.68	-12706.77	-10147.02	-2340.99
S11	Tanning and dressing of leather; manufacture of luggage, and footwear	2227.40	1740.80	-341217.27	-1948.56	-159.44	-24754.82	-456319.05	-1641.19	-1957.29	-705.09
S12	Manufacture of wood and of products of wood and cork, except furniture	930.90	1810.90	196938.80	113.63	17.30	2217.69	206905.01	955.60	1112.33	24.99
S13	Manufacture of pulp, paper, and paper products	2220.60	3851.30	844343.56	1749.70	114.64	7256.21	923881.49	5554.21	3490.76	345.42
S14	Publishing, printing, and reproduction of recorded media	1144.30	819.80	-553115.06	-1309.46	-106.32	-23691.85	-637263.37	-3031.26	-2601.16	-283.04
S15	Manufacture of coke, refined petroleum products, and nuclear fuel	6254.30	5433.70	-436102.04	-7599.09	152.10	-18000.97	-566533.38	49037.20	-33328.17	-182.84
S16	Manufacture of chemicals and chemicals products	11272.50	18270.40	1010040.66	-1842.82	1338.13	751703.00	2137864.94	10968.28	-2179.18	2352.84
S17	Manufacture of rubber and plastic products	4183.70	4520.00	717248.01	1764.31	39.51	79083.66	845629.32	5895.47	2750.21	127.02
S18	Manufacture of other non-metallic mineral products	3772.40	1972.20	8193855.81	1933.58	382.04	22317.04	8375210.10	33252.87	22589.25	156.02
S19	Manufacture of basic metals	5889.90	9060.40	7161252.67	5861.61	588.64	172134.35	7638959.33	43976.83	20961.07	324.31
S20	Manufacture of fabricated metal products, except machinery and equipment	3495.30	3872.80	-376228.55	-1242.56	-71.95	-24999.89	-449626.89	-733.85	-2234.87	-107.77
S21	Manufacture of machinery and equipment	8650.10	15945.90	-3813734.42	-5294.60	-447.25	-144585.90	-4208153.52	-21418.22	-15978.32	-689.40
S22	Manufacture of office machinery and computers	1945.50	5323.40	-1545252.27	-1968.91	-190.31	-64133.58	-1709729.50	-8922.80	-6512.53	-333.48
S23	Manufacture of electrical machinery and apparatus	4004.20	5366.60	147408.44	-437.29	-10.03	35421.22	170536.19	1376.90	311.95	-35.20
S24	Manufacture of radio, television and communication equipment and apparatus	3628.20	9584.50	-2261106.98	-2686.73	-265.10	-86070.39	-2485779.23	-13250.16	-9105.02	-408.25
S25	Manufacture of medical, precision and optical instruments, watches and clocks	1421.50	4354.20	-1292405.39	-1553.77	-145.89	-48444.15	-1418704.15	-7461.93	-5292.59	-231.89
S26	Manufacture of motor vehicles, trailers, and semi-trailers	29237.60	29476.60	-6177645.14	-10050.37	-927.39	-331600.28	-7007792.62	-33090.18	-27092.52	-1615.58
S27	Manufacture of other transport equipment	3791.90	3072.70	-811776.89	-1228.53	-111.93	-34793.31	-907068.72	-4339.81	-3446.89	-176.25
S28	Manufacture of furniture	2629.90	3254.70	-2283504.62	-5345.13	-397.30	-90885.14	-2609799.07	-12525.99	-10566.63	-1159.53
S29	Recycling	0.00	0.00	-127.96	-0.21	-0.01	-3.87	-140.79	-0.68	-0.59	-0.02
S30	Electricity, gas, steam, and hot water supply	124.30	118.20	-1778712.20	-10655.97	-168.06	-14399.63	-2068984.80	-1583.48	-13590.24	-156.54
S31	Collection, purification, and distribution of water	0.00	0.00	-172475.71	-411.20	-21.47	-5217.26	-192982.82	-797.26	-913.45	-35.45
S32	Construction	8.00	9.00	-12460965.09	-20462.03	-1674.59	-465503.97	-13875293.31	-63959.16	-55426.22	-3412.09
S33	Wholesale and retail trade; repair of motor vehicles, and personal goods	8712.50	956.00	-3892452.38	-7653.69	-661.62	-232926.56	-4491208.18	-17741.80	-18954.83	-1009.45
S34	Hotels and restaurants	0.00	131.00	-5584275.15	-63976.58	-3424.47	-198014.23	-8187382.93	-24710.39	-37377.91	-18746.32
S35	Land transport; transport via pipelines	3385.40	370.00	353429.17	619.29	4.57	-6754.38	361097.10	-1990.31	3602.95	10.74
S36	Water transport	1062.00	67.00	1242618.51	274.67	47.06	2100.26	1265076.07	11024.90	22520.64	63.80
S37	Air transport	3282.00	1998.00	2073058.60	-222.02	66.45	-2371.55	2086625.24	1701.61	6267.94	10.83
S38	Supporting and auxiliary transport activities; activities of travel agencies	2397.00	1766.00	190621.62	152.55	6.47	-50.88	195780.78	1012.17	1297.23	23.10
S39	Post and telecommunications	738.00	812.00	-443488.76	-839.00	-55.62	-13387.06	-491737.14	-1884.46	-2205.91	-113.90
S40	Financial intermediation	1880.00	1292.00	-423777.39	-1075.33	-62.33	-13386.44	-479067.09	-953.98	-2405.32	-154.87
S41	Real estate, renting, and business activities	10346.00	13125.00	-2574045.84	-5972.43	-420.47	-120512.34	-2950323.73	-10835.07	-13338.91	-896.31
S42	Public administration and defense; compulsory social security	0.00	0.00	-2342071.30	-5815.72	-342.29	-69057.71	-2639368.61	-10817.48	-11837.35	-890.90
S43	Education	0.00	0.00	-966026.61	-2791.69	-157.97	-27011.69	-1100635.67	-4426.29	-5281.92	-469.01
S44	Health and social work	0.00	0.00	-3990323.30	-8178.89	-1119.36	-418218.63	-4927300.26	-22136.89	-17770.51	-2548.69
S45	Other community, social, and personal service activities	776.00	2050.00	-1632980.34	-5439.90	-447.68	-65336.94	-1951336.35	-8069.39	-8497.27	-1654.32
S46	Private households with employed persons	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**151658.00**	**192944.00**	**-40171386.68**	**-43146.74**	**-3532.57**	**-1985568.85**	**-44158135.07**	**-147062.00**	**-239149.86**	**6677.03**

Source: own elaboration from 2000 Spanish NAMEA.

* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.

Table D.2: Emission balances by sector according expression (16), Spain 2000

Units: million euros and tones

		Total exports 2000	Total imports 2000	Greenhouse gases					Other gases		
				CO_2	CH_4	N_2O	Synthetic gases*	Total in CO_2 equivalent	SO_2	NO_x	NH_3
S1	Agriculture, hunting, and related services activities	7027.00	4877.60	1628181.92	82009.54	4102.45	35489.64	4657630.14	4853.83	19660.63	25792.74
S2	Forestry, logging, and related services activities	154.60	498.60	-155672.40	-4006.72	-204.22	-2530.59	-305651.67	-397.48	-2420.88	-1256.16
S3	Fishing	319.80	764.90	-891907.94	-713.70	-62.48	-4144.37	-930409.70	-1982.57	-13481.59	-179.51
S4	Mining of coal and lignite; extraction of peat	1.40	875.70	-479200.74	-32626.59	-42.10	-6668.20	-1184077.18	-2912.26	-2930.71	-51.92
S5	Extraction of crude petroleum, natural gas; uranium and thorium ores	3.40	15513.30	-24058230.99	-38732.15	-1617.11	-64772.45	-25437682.56	-39439.15	-183709.67	-1114.53
S6	Mining of metal ores	98.50	1151.80	-1263284.31	-744.51	-88.71	-20939.88	-1327360.40	-3129.67	-13940.28	-118.35
S7	Other mining and quarrying	503.50	527.10	-16838.80	-21.13	-1.79	-506.59	-18344.53	-107.81	-87.64	-2.69
S8	Manufacture of food products, beverages, and tobacco	9219.30	10842.80	-1143647.35	-23739.44	-1214.79	-23024.38	-2041786.35	-4470.31	-9754.37	-7347.34
S9	Manufacture of textile	2919.30	3693.80	-535593.46	-2597.22	-179.27	-46900.39	-692609.60	-3288.15	-2530.01	-700.05
S10	Manufacture of wearing apparel; dressing, and dyeing of fur	1999.80	3773.30	-863439.27	-3236.52	-229.24	-54115.69	-1056587.43	-5235.40	-3994.46	-849.97
S11	Tanning and dressing of leather; manufacture of luggage, and footwear	2227.40	1740.80	217887.46	1374.98	68.68	11237.87	279290.27	1254.07	1071.11	297.43
S12	Manufacture of wood and of products of wood and cork, except furniture	930.90	1810.90	-470323.77	-1681.00	-110.50	-10763.94	-550642.28	-2256.31	-2986.76	-468.63
S13	Manufacture of pulp, paper, and paper products	2220.60	3851.30	-1407686.81	-3045.29	-202.18	-25351.13	-1559666.16	-8665.69	-6183.03	-562.06
S14	Publishing, printing, and reproduction of recorded media	1144.30	819.80	146898.99	266.40	22.49	4038.54	163504.82	947.81	633.17	57.57
S15	Manufacture of coke, refined petroleum products, and nuclear fuel	6254.30	5433.70	1730146.80	1845.60	145.35	3853.77	1817817.33	10039.11	8846.97	65.72
S16	Manufacture of chemicals and chemicals products	11272.50	18270.40	-7309974.58	-9064.55	-2868.82	-1325767.45	-9715431.66	-45246.16	-26898.13	-5349.64
S17	Manufacture of rubber and plastic products	4183.70	4520.00	-212874.71	-383.66	-50.69	-28064.74	-264711.09	-1414.43	-840.55	-101.46
S18	Manufacture of other non-metallic mineral products	3772.40	1972.20	4694685.38	1780.43	250.31	23949.19	4833618.79	19384.08	13869.24	166.61
S19	Manufacture of basic metals	5889.90	9060.40	-5266706.38	-5690.01	-461.08	-132964.18	-5662093.99	-30710.91	-18758.92	-362.22
S20	Manufacture of fabricated metal products, except machinery and equipment	3495.30	3872.80	-301244.36	-345.74	-29.42	-8190.26	-325816.81	-1847.51	-1196.01	-39.65
S21	Manufacture of machinery and equipment	8650.10	15945.90	-4080881.70	-4724.33	-453.89	-134496.85	-4455294.98	-23527.82	-16422.61	-705.65
S22	Manufacture of office machinery and computers	1945.50	5323.40	-1696580.35	-2023.09	-201.72	-66832.62	-1868430.25	-9933.81	-7067.57	-357.11
S23	Manufacture of electrical machinery and apparatus	4004.20	5366.60	-994571.48	-1097.52	-104.62	-59681.59	-1109731.99	-5799.49	-4113.78	-146.05
S24	Manufacture of radio, television and communication equipment and apparatus	3628.20	9584.50	-3123378.60	-3302.93	-348.96	-104400.86	-3405318.38	-18658.57	-12218.96	-514.11
S25	Manufacture of medical, precision and optical instruments, watches and clocks	1421.50	4354.20	-1190622.14	-1369.41	-132.53	-44875.98	-1305339.80	-7082.94	-4921.22	-221.07
S26	Manufacture of motor vehicles, trailers, and semi-trailers	29237.60	29476.60	-169934.62	-207.39	-20.84	-8251.32	-189001.59	-1059.56	-655.86	-32.75
S27	Manufacture of other transport equipment	3791.90	3072.70	461424.77	516.14	55.19	19639.15	509011.87	2693.21	1742.53	81.50
S28	Manufacture of furniture	2629.90	3254.70	-324481.85	-573.86	-49.03	-12009.99	-363740.98	-1679.56	-1555.05	-131.33
S29	Recycling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S30	Electricity, gas, steam, and hot water supply	124.30	118.20	31475.19	34.36	1.04	25.47	32545.55	317.33	118.11	0.29
S31	Collection, purification, and distribution of water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S32	Construction	8.00	9.00	-621.60	-0.81	-0.07	-11.62	-670.83	-2.93	-2.42	-0.18
S33	Wholesale and retail trade; repair of motor vehicles, and personal goods	8712.50	956.00	2490329.55	7264.49	499.54	88091.37	2885832.85	14857.61	11917.51	1908.62
S34	Hotels and restaurants	0.00	131.00	-38882.97	-461.05	-24.22	-740.27	-56812.18	-210.56	-269.51	-139.82
S35	Land transport; transport via pipelines	3385.40	370.00	1859551.43	2824.91	155.89	14188.15	1981387.26	5567.98	11781.39	196.08
S36	Water transport	1062.00	67.00	1495949.58	710.14	76.79	6358.04	1541025.13	12250.79	23903.39	125.63
S37	Air transport	3282.00	1998.00	1557453.49	710.80	86.13	6200.75	1605279.99	3028.92	6186.20	97.39
S38	Supporting and auxiliary transport activities; activities of travel agencies	2397.00	1766.00	241324.21	439.18	29.41	5430.24	265095.02	1123.54	1384.54	76.59
S39	Post and telecommunications	738.00	812.00	-16850.57	-21.37	-1.55	-216.74	-17995.74	-106.66	-66.88	-3.33
S40	Financial intermediation	1880.00	1292.00	145216.28	224.73	15.64	1749.44	156534.74	1029.25	567.69	41.08
S41	Real estate, renting, and business activities	10346.00	13125.00	-540083.32	-886.27	-80.99	-13245.44	-597048.33	-3403.93	-2242.54	-238.07
S42	Public administration and defense; compulsory social security	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S43	Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S44	Health and social work	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S45	Other community, social, and personal service activities	776.00	2050.00	-318396.67	-1852.24	-260.66	-6352.95	-444452.40	-1839.88	-1582.93	-1236.55
S46	Private households with employed persons	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**151658.00**	**192944.00**	**-40171386.68**	**-43146.74**	**-3532.57**	**-1985568.85**	**-44158135.07**	**-147062.00**	**-239149.86**	**6677.03**

Source: own elaboration from 2000 Spanish NAMEA.

* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units..

Table D.3: Key sectors according expression (15), Spain 2000

CO_2	CH_4	N_2O	Synthetic gases*	Total in CO_2 equivalent
S32 Construction	S8 Manufacture of food S34 Hotels and restaurants	S8 Manufacture of food S34 Hotels and restaurants	S32 Construction S44 Health and social work S8 Manufacture of food	S32 Construction S8 Manufacture of food S34 Hotels and restaurants

SO_2	NO_x	NH_3
S32 Construction	S32 Construction	S1 Agriculture

Source: own elaboration from 2000 Spanish NAMEA.
* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.

Table D.4: Key sectors according expression (16), Spain 2000

CO_2	CH_4	N_2O	Synthetic gases*	Total in CO_2 equivalent
S5 Extraction of petroleum S16 Manufacture of chemicals	S5 Extraction of petroleum S4 Mining of coal and lignite S8 Manufacture of food	S5 Extraction of petroleum S16 Manufacture of chemicals	S16 Manufacture of chemicals	S5 Extraction of petroleum S16 Manufacture of chemicals

SO_2	NO_x	NH_3
S16 Manufacture of chemicals S5 Extraction of petroleum S19 Manufacture of basic metals	S5 Extraction of petroleum	S1 Agriculture

Source: own elaboration from 2000 Spanish NAMEA.
* Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent units.