Preliminary draft

Ecological impact of household activity in Spain: a new approximation to ecological footprints*

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Abstract:

The objective of this paper is to analyse the environmental impact of the Spanish economy by way of seven water pollution and atmospheric emissions footprints. These were obtained on the basis of the Spanish Accounting Matrix for 1999. Only households were taken as an exogenous account, while government, labour, capital and other accounts were treated as endogenous. The data base was obtained from the Spanish Statistical Institute.

The analysis reveals that pollution in Spain is closely linked to food production, energy, extractive industries and paper manufacturing. We show that services, taken as a whole, are major polluters, though this is due to the volume of household expenditure they represent rather than their pollution potential as such. We also show that the Spanish economy avoids a great deal of pollution by importing inputs, which pollute where they are produced.

The ecological footprints, or *per capita* pollution, are estimated for seven categories of pollution. As might be expected, the values obtained are significantly dependent on income levels and grow in line with them. Nevertheless, where overall income remains the same, poorer households are more polluting than richer ones.

Key words: Ecological footprint, CO_2 emissions, water pollution, Social Accounting Matrix, Spanish economy

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1. Introduction

Since Wackernagel and Rees first popularised the concept of the "Ecological Footprint" in 1996 as "*the total land and water area required to support a population with a specific lifestyle and given technology with all necessary natural resources and to absorb all wastes and emissions for an indefinite length of time*" (Wackernagel and Rees, 1996), numerous papers have sought both to establish its theoretical validity as a measure of the sustainability of a given lifestyle and to develop and refine the calculation techniques applied to specific populations (see Wackernagel and Rees, 1996; Bicknell et al., 1998; Wackernagel et al., 1999; Loh, 2000; and Ferng 2001 and 2002). It is a sign of the interest awakened by this concept that over 50 papers concerned with the ecological footprint have been published in leading journals since 1996, and that the Ecological Economics Society should have set up a discussion forum on the subject in 2000, publishing the studies submitted in volume 29 of *Ecological Economics.*

Despite some criticism of the use that has been made of the Ecological Footprint (EF) as a measure of humanity's appropriation of ecosystems[1], there can be no doubt that EF has opened up a debate on the need for environmental indicators capable of reflecting the pressure put on the environment by the economic activities and consumption of a given population.

In this context, our objective is to assess the environmental impact of the lifestyle enjoyed by the population of Spain, which is to say, we seek to estimate the EF associated with household activity. Strictly speaking, the calculation of the EF involves converting the consumption of resources and the production of waste in given areas of land and water, which absorb waste and generate resources on an ongoing basis (Ferng, 2002). The conversion of environmental impacts into a single physical measure may, however, conceal a more important reality, which is that the effects of human activities vary considerably depending on the resource or pollution considered and in many cases require clearly differentiated policy responses. For this reason, we shall treat any measure of pollution or environmental impact associated with the economic activity of any individual as an ecological footprint, though we are of course aware that this is stretching the literal meaning of the concept. Specifically, we shall focus on the air and

[1] For example, Van den Bergh and Verbruggen (1999) argue that the ecological footprint depends on the objectives of the analysis concerned, while other scholars such as Ayres (2000), Herendeen (2000) and Ferng (2002) have criticised the failure of the concept to provide useful information for energy policy making aimed at achieving sustainable development.

water pollution attributable to the consumption of goods and services by individuals in Spain, which we shall reflect in terms of three atmospheric pollutants (CO_2, NO_X and SO_X) and four indicators for water (waste water, nitrogen, metals and biological demand in oxygen (BDO).

The activities of households generates demand for goods and services, which must either be produced locally or imported. Production, meanwhile, requires the direct use of inputs from various sectors, which in turn use inputs from other sectors (indirect use) in the different stages of the industrial process. Recognising the direct and indirect demand generated between industries, some studies have used the input-output model as a systematic, standard method for the calculation of the EF. Thus, Bicknell et al., 1998; Ferng, 2002; Hubacek and Giljum, 2003 and McDonald and Patterson, 2004, among others, use the input-output methodology to calculate the pollution (or the equivalent area of land) associated with the direct and indirect inputs needed by the productive sectors of the economy to meet final demand.

Given that household activity is closely linked to other institutional activities, however, we have expanded the Leontief model to include other activities that are not directly related with production, working within the framework of the Social Accounting Matrix (SAM). This change in the benchmark model is, at the best of our knowledge, a methodological innovation, and it focuses on the relationships between industry and other institutional sectors in order to understand more clearly how pollution is generated and circulates in the economy in order to satisfy certain specific consumption patterns.

If the SAM model is to be applied to the consideration of pollution, it is necessary also to examine certain issues that are absent from the conventional input-output model. The first such question is whether the formal change from the input-output to the SAM model has any effect on the computation of the pollution associated with the economy concerned. From an economic standpoint, it is well known that the multipliers associated with a SAM model are greater than those of the input-output model. As we shall see below, however, the pollution associated with an economy does not depend on the model used to explain it, because pollution is a purely physical process. Thus, the use of a SAM model facilitates understanding of how the pollution associated with household activity “circulates” throughout the map of the economy without raising the total associated pollution.

Secondly, since we are interested in estimating the pollution associated with household activity, we may assume that all other industries and institutions work to meet the needs of households. Consequently, both productive sectors and institutional accounts (labour, capital, government, savings-investment), as well overseas accounts, are endogenous to the model, generating pollution to meet household consumption, the only exogenous accounts. As a result, we attribute to households both the pollution generated within the country itself and pollution imported in the form of inputs or end goods, assigning to the Spanish economy the pollution it "avoids" by buying goods and services produced abroad.

This approach thus represents a step forward in the study of the pollution associated with a given population both from the methodological standpoint and empirically. Methodologically, we expand the input-output model, which focuses very closely on the productive side of the economy, to include other institutions that generate and redistribute income (overseas sector, government, savings-investment processes) in order to obtain a more accurate picture of the causes and flow of the pollution associated with the demand for goods. Secondly, the use of a SAM table enables us more easily to include the pollution associated with imports and generated by households as a result of consumption, enabling us to understand better the role of demand and household spending in the pollution produced by the Spanish economy, a matter that has been ignored in the literature to date.

Finally, from the empirical point of view, the calculation of the environmental impacts associated with household activity as an indicator of the ecological footprint of the Spanish economy represents a new approach which we believe will be of use for economic policy making, in particular because it includes the pollution contained in imports and household pollution.

The structure of this paper is as follows: Section 2 provides a discussion of the methodology, presenting the initial model and the indicators that will be used for the analysis of Spanish pollution. In section 3 we describe the main results, divided into three subsections, the first of which employs the matrix of SAM multipliers and the pollution scores obtained. The second breaks this matrix down into two sub-matrices separating productive and institutional effects. In the third subsection, we calculate pollution per head of population, which we associate with the ecological footprints, and consider the contribution of different types of household to total pollution. Finally, in section 4 we discuss our main conclusions.

2. Methodology

As explained in the introduction, our objective is to analyse the environmental impacts associated with Spanish household spending to obtain an approximation to the ecological footprint associated with the country's population. The use of a SAM will allow us to split environmental effects into those associated with direct production activities and those related with other kinds of economic activity which do not directly cause pollution but are nevertheless relevant to production that does pollute. In particular, we shall examine the role played by foreign trade, savings and government, given their relationship with households.

Table 1 represents the typical structure of SAM grouped into six aggregate accounts. Here, $\mathbf{X}_{ij}$ is the matrix reflecting payments made from accounts *j* to accounts *i.* The structure is similar to that used in this study for the Spanish economy in 1999, a more disaggregated representation of which is provided below.

(Insert Table 1)

Given our objective, we shall consider the exogenous accounts forming aggregate account 6, Households. The columns for this account reflect household consumption expenditure, investments and taxes paid. The rows, meanwhile, reflect income received by households from work and investments, as well as transfers received from government and abroad. For the purposes of analysis, we shall classify the endogenous accounts into two groups. The first is formed by type 1 and 2 accounts (productive sectors and overseas sector), while the second includes type 3, 4 and 5 accounts (factors of production, i.e. labour and capital, companies and government, and savings-investment). The aim here is to contrast productive accounts (domestic and foreign) and institutional accounts.

Following the selection of the exogenous, the equations associated with the SAM represented in Table 1 may be expressed as follows:

$$\begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \\ \mathbf{x}_3 \\ \mathbf{x}_4 \\ \mathbf{x}_5 \end{bmatrix} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & 0 & \mathbf{A}_{14} & \mathbf{A}_{15} \\ \mathbf{A}_{21} & 0 & \mathbf{A}_{23} & \mathbf{A}_{24} & \mathbf{A}_{25} \\ \mathbf{A}_{31} & \mathbf{A}_{33} & 0 & 0 & 0 \\ \mathbf{A}_{41} & \mathbf{A}_{42} & \mathbf{A}_{43} & \mathbf{A}_{44} & 0 \\ 0 & 0 & 0 & \mathbf{A}_{54} & 0 \end{bmatrix} \begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \\ \mathbf{x}_3 \\ \mathbf{x}_4 \\ \mathbf{x}_5 \end{bmatrix} + \begin{bmatrix} \mathbf{X}_{16} \\ \mathbf{X}_{26} \\ \mathbf{X}_{36} \\ \mathbf{X}_{46} \\ \mathbf{X}_{56} \end{bmatrix} \Leftrightarrow \mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y}\,, \qquad (1)$$

which may also be represented as:

$$\begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \\ \mathbf{x}_3 \\ \mathbf{x}_4 \\ \mathbf{x}_5 \end{bmatrix} = \begin{bmatrix} \mathbf{M}_{11} & \mathbf{M}_{12} & \mathbf{M}_{13} & \mathbf{M}_{14} & \mathbf{M}_{15} \\ \mathbf{M}_{21} & \mathbf{M}_{22} & \mathbf{M}_{23} & \mathbf{M}_{24} & \mathbf{M}_{25} \\ \mathbf{M}_{31} & \mathbf{M}_{32} & \mathbf{M}_{33} & \mathbf{M}_{34} & \mathbf{M}_{35} \\ \mathbf{M}_{41} & \mathbf{M}_{42} & \mathbf{M}_{43} & \mathbf{M}_{44} & \mathbf{M}_{45} \\ \mathbf{M}_{51} & \mathbf{M}_{52} & \mathbf{M}_{53} & \mathbf{M}_{54} & \mathbf{M}_{55} \end{bmatrix} \begin{bmatrix} \mathbf{X}_{16} \\ \mathbf{X}_{26} \\ \mathbf{X}_{36} \\ \mathbf{X}_{46} \\ \mathbf{X}_{56} \end{bmatrix} \Leftrightarrow \mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} = \mathbf{My} \ , \qquad (2)$$

where **M** is the general multiplier matrix.

Matrix **A** can be further broken down into two, partially separating productive and institutional accounts, as follows:

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & 0 & 0 & 0 \\ \mathbf{A}_{21} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 & \mathbf{A}_{14} & \mathbf{A}_{15} \\ 0 & 0 & \mathbf{A}_{23} & \mathbf{A}_{24} & \mathbf{A}_{25} \\ \mathbf{A}_{31} & \mathbf{A}_{33} & 0 & 0 & 0 \\ 0 & \mathbf{A}_{42} & \mathbf{A}_{43} & \mathbf{A}_{44} & 0 \\ 0 & 0 & 0 & \mathbf{A}_{54} & 0 \end{bmatrix} = \mathbf{B}_1 + \mathbf{B}_2 \qquad (3)$$

Based on this breakdown, if we define $\mathbf{D} = (\mathbf{I}-\mathbf{B}_1)^{-1}\mathbf{B}_2$, we obtain:

$$\mathbf{M} = (\mathbf{I}-\mathbf{B}_1-\mathbf{B}_2)^{-1} = (\mathbf{I}-\mathbf{D}^2)^{-1}(\mathbf{I}+\mathbf{D})(\mathbf{I}-\mathbf{B}_1)^{-1} = \mathbf{M}_3\,\mathbf{M}_2\,\mathbf{M}_1$$

$$\mathbf{x} = (\mathbf{I}-\mathbf{D}^2)^{-1}(\mathbf{I}+\mathbf{D})(\mathbf{I}-\mathbf{B}_1)^{-1}\,\mathbf{y} = \mathbf{M}_3\,\mathbf{M}_2\,\mathbf{M}_1\mathbf{y} \qquad (4)$$

In this expression, $\mathbf{M}_1$ measures *own group effects*. We may observe that $\mathbf{M}_1\mathbf{y}$ reflects the effects of household consumption on the economy formed solely by production and overseas trade activities. This economy is defined by the following equations

$$\begin{bmatrix} \mathbf{r}_1 \\ \mathbf{r}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} \\ \mathbf{A}_{21} & 0 \end{bmatrix} \begin{bmatrix} \mathbf{r}_1 \\ \mathbf{r}_2 \end{bmatrix} + \begin{bmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \end{bmatrix}, \qquad (5)$$

the matrix of which is the expansion of the matrix of technical coefficients in the input-output table to include the coefficients for overseas trade accounts. Consequently, we shall refer to system (5) as the expanded system in what follows. Also, let us know that $\mathbf{M}_1\mathbf{y}$ is nothing more than $(\mathbf{r}_1',\mathbf{r}_2',\mathbf{y}_3',\mathbf{y}_4',\mathbf{y}_5')'$.

In (4) $\mathbf{M}_2$ measures *open-loop effects*. $\mathbf{M}_2\mathbf{M}_1\mathbf{y}$ may be split into two parts. One part is the aforementioned $\mathbf{M}_1\mathbf{y}$ effects. The other is $(\mathbf{I}-\mathbf{B}_1)^{-1}\mathbf{B}_2\mathbf{M}_1\mathbf{y}$, which are essentially the *own group effects* of demand $\mathbf{B}_2\mathbf{M}_1\mathbf{y}$, formed by the direct effect of *own group effects* on the institutional accounts.

Finally, $\mathbf{M}_3$ measures *closed-loop effects*, reflecting other effects with more complex feedback loops.

This may be better understood through an additive rather than a multiplier-based breakdown. This gives

$$\mathbf{x} - \mathbf{y} = (\mathbf{M}-\mathbf{I})\,\mathbf{y} = [\mathbf{N}_3 + \mathbf{N}_2 + \mathbf{N}_1]\mathbf{y},$$

where $\mathbf{N}_1 = \mathbf{M}_1\mathbf{-I}$, $\mathbf{N}_2 = (\mathbf{M}_2\mathbf{-I})\mathbf{M}_1$ y $\mathbf{N}_3 = (\mathbf{M}_3\mathbf{-I})\mathbf{M}_2\mathbf{M}_1$

Hence, we may break down **x - y**, which is the total net effect, into three components:

$$\mathbf{N}_1\mathbf{y} = (\mathbf{M}_1\mathbf{-I})\,\mathbf{y} = ((\mathbf{I-B}_1)^{-1}\mathbf{-I})\,\mathbf{y} = (\mathbf{B}_1 + \mathbf{B}_1^2 + .. + \mathbf{B}_1^n + ..)\mathbf{y},$$

$$\mathbf{N}_2\mathbf{y} = (\mathbf{M}_2\mathbf{-I})\mathbf{M}_1\mathbf{y} = \mathbf{D}(\mathbf{I-B}_1)^{-1}\mathbf{y} = (\mathbf{I-B}_1)^{-1}\mathbf{B}_2(\mathbf{I-B}_1)^{-1}\mathbf{y} = (\mathbf{I-B}_1)^{-1}\mathbf{y}_{\text{ind}}, \quad (6)$$

$$\mathbf{N}_3\mathbf{y} = \mathbf{x} - \mathbf{y} - \mathbf{N}_1\mathbf{y} - \mathbf{N}_2\mathbf{y} = (\mathbf{M-I})\mathbf{y} - \mathbf{N}_1\mathbf{y} - \mathbf{N}_2\mathbf{y}.$$

We may observe here that $\mathbf{N}_1\mathbf{y}$ represents *net own group effects* and that they coincide with the *net effects* produced by demand $(\mathbf{y}_1\text{'},\mathbf{y}_2\text{'})$ in the expanded system. These are, then, the net direct and indirect production requirements of the economy formed exclusively by productive industries and the overseas sector to meet household expenditure on goods produced by the economy.

The component $\mathbf{N}_2\mathbf{y}$ also represents the direct and indirect production requirements of the expanded system if it is to meet demand $\mathbf{y}_{\text{ind}} = \mathbf{B}_2(\mathbf{I-B}_1)^{-1}\mathbf{y}$, which we shall call induced demand. The expenditures **y** made by households produce their own group effects, $(\mathbf{I-B}_1)^{-1}\mathbf{y}$, which in turn induce expenditures $\mathbf{y}_{\text{ind}} = \mathbf{B}_2(\mathbf{I-B}_1)^{-1}\mathbf{y}$ in institutional accounts. Hence, we may define $\mathbf{N}_2\mathbf{y}$ as the *own group effects* associated with expenditures directly induced by $\mathbf{N}_1\mathbf{y}$ in the institutional accounts. The remaining effects that are not reflected by either $\mathbf{N}_1\mathbf{y}$ or $\mathbf{N}_2\mathbf{y}$ are captured by $\mathbf{N}_3\mathbf{y}$.

This breakdown can also been seen in dependency chains, which help understand their significant. Based on (2), and taking into account that

$$\mathbf{M-I} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{-I} = \mathbf{A} + \mathbf{A}^2 + .. + \mathbf{A}^n + ..,$$

x_i-y_i is given by

$$x_i - y_i = \sum_j \sum_{\{j_1,\dots,j_n\}} a_{i,j_1} a_{j_2,j_3} .. a_{j_{n-1},j_n} a_{j_n,j} y_j \,, \quad (7)$$

which is the total net effect of the household expenditures **y** on the account *i*. If we use I_p to denote the set of indices of productive accounts (productive industries and overseas sector), the non null addends included in the above expression of x_i-y_i can be broken down into three groups, as follows:

a) Those in which $a_{i,j_1} a_{j_2,j_3} .. a_{j_{n-1},j_n} a_{j_n,j}$ has only $a_{r,s}$ with $r, s \in I_p$,

b) Those in which $a_{i,j_1} a_{j_2,j_3} .. a_{j_{n-1},j_n} a_{j_n,j}$ has one and only one $a_{r,s}$ with r ó $s \notin I_p$,

c) Those in which $a_{i,j_1} a_{j_2,j_3} .. a_{j_{n-1},j_n} a_{j_n,j}$ has more than one $a_{r,s}$ with r ó $s \notin I_p$,

Here we may observe that the sum of a), b) and c) are nothing more than the component *i* of $\mathbf{N}_1\mathbf{y}$, $\mathbf{N}_2\mathbf{y}$ and $\mathbf{N}_3\mathbf{y}$ respectively. Hence, $\mathbf{N}_1\mathbf{y}$ are the effects arising exclusively due to the expanded system, which is to say the productive accounts. $\mathbf{N}_2\mathbf{y}$ are the effects arising when the institutional accounts intervene in the productive process in a single step. Finally, $\mathbf{N}_3\mathbf{y}$ are the effects produced when the intervention of productive accounts is greater.

Having considered the significance of $\mathbf{My}$, $\mathbf{N}_1\mathbf{y}$, $\mathbf{N}_2\mathbf{y}$ and $\mathbf{N}_3\mathbf{y}$, we may now adapt these expressions to reflect the pollution or environmental impact associated with household demand, **y**. It is well known that one way of including the valuation of input, whether in terms of labour, value added, a natural resource or environmental pollution in the model described by (1) and (2) is to perform a preliminary multiplication of the matrix of multipliers **M** by the pertinent unit vector in order to obtain a vector of unit values for the pollution in question. Specifically, if **c** is a pollution vector, the vector of pollution values will be $\Lambda = (\lambda_i) = \mathbf{c'M}$, while the pollution attributable to expenditure **y** in the exogenous account will be $\mathbf{c'My}$. Each λ_i, which is equal to $\lambda_i = \sum_r c_r m_{r,i}$, represents the necessary direct or indirect pollution for each unit of expenditure i in the households account, which is the exogenous account.

Based on the breakdown of **M** into the three $\mathbf{N}_i$ components, the pollution associated with an expenditure **y** may also be disaggregated into four parts: $\mathbf{c'N_1y}$, $\mathbf{c'N_2y}$, $\mathbf{c'N_3y}$ and $\mathbf{c'y}$, validating:

$$\mathbf{c'My} = \mathbf{c'N_1y} + \mathbf{c'N_2y} + \mathbf{c'N_3y} + \mathbf{c'y}.$$

We may note that $\mathbf{c'N_1y}$ is the net pollution resulting from expenditure **y** for the economy associated with the expanded system. Meanwhile, $\mathbf{c'N_2y}$ is the pollution associated with the induced demand referred to above. Finally, $\mathbf{c'N_3y}$ reflects the remaining pollution that is not captured by either $\mathbf{N_1y}$, $\mathbf{N_2y}$ or $\mathbf{c'y}$.

Having established the valuation technique, it is now necessary to resolve the methodological question referred to in the Introduction. This issue may be summarized as follows. Does the use of an open Leontief model based on a SAM rather than a conventional input-output model increase the measured amount of pollution? The answer depends on the context and requires some explanation. In general, using a model constructed on the basis of a SAM will not raise the amount of pollution, because it is a physical reality that cannot be increased by a formal process. If the overall measure increases, this can only be because certain instances of pollution are not accounted for in the simple model constructed on the basis of the input-output table. For example, we can use an input-output table based on sub-matrix $\mathbf{A}_{11}$ in the present case to calculate the pollution generated by productive activities to satisfy final demand (which contains household consumption). However, this will leave out pollution generated directly by households, which must be added to obtain an estimate of the actual pollution produced by the population. Similarly, it will be necessary to estimate the pollution associated with the imports made by the economy and add it to the preceding aggregate. This imported pollution is not usually considered in input-output models, although it can be estimated by making certain assumptions (see Sánchez-Chóliz and Duarte (2004)).

The SAM model, on the other hand, allows us to deal with all three types of pollution as if they were internally produced. Specifically, imported pollution has been included by assigning a positive value to the overseas sector coefficient in the direct pollution vector, while the direct pollution produced by households is accounted for by way of a positive coefficient for the labour factor in the vector. Furthermore, the benchmark final demand is not the whole final demand of the economy, since we consider only household consumption as an exogenous account, but only the demand associated with household expenditure. Consequently, the pollution values per unit of household expenditure will be higher than values per unit of final demand in the input-output model, because pollution is higher while the associated income is lower.

This can be explained in more detail using (2). The pollution vector $\mathbf{c'}$ can be broken down into five sub-vectors in accordance with the aggregate accounts of (2). Let $\mathbf{c'}= (\mathbf{c_1', c_2', c_3', c_4', c_5'})$. The total pollution produced by all own processes is given by V= $\mathbf{c'My}$ and also by V= $\mathbf{c'x} = \mathbf{c_1'x_1 + c_2'x_2 + c_3'x_3 + c_4'x_4 + c_5'x_5}$. Because of the way we have constructed the model, $\mathbf{c_1'x_1}$ represents the total pollution generated by own production processes. Since index 2 represents overseas trade, $\mathbf{c_2'x_2}$ is the pollution imported from other countries. Similarly, because 3 is the factors account and we associate household pollution with labour, $\mathbf{c_3'x_3}$ represents the pollution produced by households when they consume goods. Finally, indices 4 and 5 represent institutional sectors with null direct pollution, and we may therefore assert that $\mathbf{c_4'x_4 + c_5'x_5} = 0$.

In the open model constructed on the basis of the input-output tables, the parallel relations to (1) and (2) we would obtain from Table 1 would be:

$$\mathbf{x_1} = \mathbf{A_{11}}\,\mathbf{x_1} + \mathbf{A_{12}}\,\mathbf{x_2} + \mathbf{A_{14}}\,\mathbf{x_4} + \mathbf{A_{15}}\,\mathbf{x_5} + \mathbf{X_{16}} \Leftrightarrow \mathbf{x_1} = \mathbf{A_{11}}\,\mathbf{x_1} + \mathbf{z} \Leftrightarrow \mathbf{x_1} = (\mathbf{I}-\mathbf{A_{11}})^{-1}\,\mathbf{z}$$

The overall pollution calculated using this model would be $\mathbf{c_1'(I-A_{11})^{-1}z} = \mathbf{c_1'x_1}$. Since $\mathbf{x_1}$ is the same in both models, the vector $\mathbf{c_1}$ is similar and pollution $\mathbf{c_1'x_1}$ measured for own processes is exactly the same.

Calculating the values by account unit, the vector of values in the model based on $\mathbf{A_{11}}$ is $\mathbf{c_1'(I-A_{11})^{-1}}$, which reflects direct and indirect pollution per unit of final demand, including *inter alia* household consumption and exports. However, a similar vector of values in our SAM-based model is $\mathbf{c_1'M_{11}+ c_2'M_{21}+ c_3'M_{31}+ c_4'M_{41}+ c_5'M_{51}}$. The first addend, $\mathbf{c_1'M_{11}}$, represents the part of this unit value embodied due to own processes. As we know that $\mathbf{M_{11}} \geq \mathbf{(I\text{-}A_{11})^{-1}}$, the values given by the SAM model are in general higher, even for this part of pollution. The explanation is simple. Since households are the only exogenous account, all of the processes in the economy are directly or indirectly associated with production for this account, which means there are certain processes associated with household expenditure that were not formerly included.

To sum up, the change in the model does not increase the reality of pollution, but redistributes it in order to improve understanding of the phenomenon. Thus, the SAM-based model provides a better treatment of certain components of pollution which are problematic in the input-output model and tend to be ignored.

Finally, let us briefly comment on the manner in which the pollution embodied in imported products and direct household pollution are assigned. In order to calculate the pollution associated with imports, we have assumed that production technologies in the countries of origin are similar to those used in Spain, since we do not have estimations of pollution values in those countries. Hence, imports are assigned the pollution value estimated in an input-output model using domestic coefficients. These pollution values are multiplied by the import account rows and the products have been taken as estimates of the total pollution embodied in each of these accounts. Once we know these overall values, the relevant direct pollution coefficients are defined in the usual way. Meanwhile, direct household pollution has been assigned in its entirety to labour due to the scarcity of available statistical and as a way of making the pollution associated with consumption processes endogenous. Following this allocation, the direct pollution coefficient is defined in the usual manner. If more accurate information were available as to the part of household pollution generated in different consumption activities (e.g. cars, heating and so on), it might be possible to devise alternatives for the distribution of this pollution among the different sectors producing consumer goods.

3. Main results

For the sake of clarity and ease of understanding, almost all of the results presented in this section are associated with the 12 aggregate accounts, seven of which group the 23 accounts for productive sectors, four reflect the remaining endogenous accounts and the last refers to the exogenous account, households. However, all of the quantitative data have been obtained using the model based on the maximum disaggregation, which has 31 different accounts. Thus, what appears as a value for an aggregate account is in fact a subsequent aggregation, which is therefore free from the negative effects of prior aggregation. The correlation between these aggregate accounts and the total accounts is shown in table 2.

(Insert Table 2)

As we have already said, in this study we seek to measure the physical magnitude of certain pollution components produced in the Spanish economy and estimate the related *per capita* values, which we associate with the footprints. In other words, we wish to reveal the amount of the relevant pollutant embodied in Spanish gross domestic product and the amount produced for each citizen of the country.

If we are properly to comprehend the significance of the figures given below, it will be important not to confuse direct pollution generated in the production process with the pollution value assigned to a given expenditure item or consumption associated with such expenditure. Our pollution values are estimates of the amount of each type of pollution produced in all processes involved in the direct or indirect procurement of the relevant consumption items. In other words, these values are vertically integrated. Finally, let us remember that direct pollution may be nil in a non production account, but the pollution value is not so, in general.

Numerical results

Our starting point to obtain the model described by (1) and (2) is the construction of the Social Accounting Matrix for the Spanish economy calculated for 1999. The matrix for 12 aggregate accounts is shown in Table 3. Having obtained the SAM, we may proceed to construct model (2), the basic equation for which is:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\ \mathbf{y} = \mathbf{M}\ \mathbf{y},$$

where **M** is the multiplier matrix and **y** is the households expenditure vector. Similarly, based on the total income for each account in the SAM and the statistical data for each type of pollution, obtained from the Spanish Statistical Institute (INE), we can calculate the vectors **c** representing direct pollution. These are presented in Table 4. In this table, the five highest direct coefficients for each type of pollution are shown in bold type in each column.

Based on **M** and the vectors **c,** the estimated pollution inherent in the household expenditure **y** will be **c'My**, which is the total pollution of each type in the Spanish economy. These totals are shown in Table 7.

Total pollution can be split between the various accounts to obtain the matrix V=($v_{i,j}$)= $\hat{\mathbf{c}}\mathbf{M}\hat{\mathbf{y}}$, where $v_{i,j}$ is the direct and indirect contribution from account *i* to obtain the household expenditure in account *j*, which is to say the part of the value of pollution in *j* produced by *i*. Specifically, if we wish to know the pollution produced by the different accounts for each monetary unit spent by households in account *j*, we need to look at column *j* in the matrix $\hat{\mathbf{c}}\mathbf{M}$. The sums of its columns are the pollution values for the different household expenditures. These values are no more than the backward linkages of model (2). The sums of the rows, meanwhile, are the forward linkages. We have kept the terms backward and forward linkage by analogy with those used in the models constructed on the basis of input-output tables.

The backward linkages for the accounts and pollutants are shown in Table 5. As in Table 4, the five highest values for each column or type of pollution are shown in bold type.

Tables 4 and 5 provide an excellent snapshot of pollution in the Spanish economy. In Table 5, each row shows the pollution produced per million euros of household expenditure in the relevant account. For example, in the row headed chemicals, the Table reflects that each million euros spent by households on products of this type generates 41.52 million litres of waste water, nitrogen pollution increases by 0.37 million kilos, metals by 2.35 million kilos, biological demand in oxygen by 5.37 million kilos, NO_x and SO_x pollution by 5.49 and 9.51 tonnes respectively and, finally, CO_2 emissions by 1.45 million kilos.

Consequently, Table 5 provide information about that accounts that produce the greatest pollution per unit of household expenditure. Thus, it may be easily observed that the sectors producing the highest pollution values out of the 23 making up the Spanish economy are “Minerals and metals”, which are top in 5 out of 7 pollutants, and “Energy products” and “Paper, paper articles and printed matter” with 3 top places, followed by “Agriculture and fish farming”, “Textiles, leather and shoes”, and “Rubber, plastics and other manufactures”, each with 2 top positions. On the other hand, services do not hold significant positions with the exception of “Recycling and repairs” which holds top position in NO_x.

(Insert Tables 3, 4 and 5)

Focusing on pollutants by aggregate account, we find that account 1, “Agriculture and food”, produces the highest pollution in waste water. Account 2, “Energy and extractive industries” is highly polluting in all seven cases. Account 5, “Other manufactures” is highly polluting in nitrogen, metals and BDO.

Finally, of the two accounts representing overseas trade, “Rest of the world” is in the top position in 4 out of the 7 pollutants, while “European Union” is top in 3, which suggests that the Spanish economy reduces its pollution by importing goods.

At this point, let us note that none of the accounts we have defined as institutional scores highly on pollution, although the value is nil in no case. The explanation for this is simple. These accounts have null direct pollution values, as shown in Table 4. Consequently, their whole pollution value is due to productive processes induced by household expenditures in these accounts. For example, we may consider the productive effects of taxes associated with household expenditure, which are collected by government, or household savings, which are invested in productive activities, which do generate pollution.

Finally, comparing Tables 5 and 4 we can see the differences between direct pollution and pollution values. The former tells us who pollutes, the latter for what or for whom pollution is produced. In Table 4, direct pollution in the sectors “Energy products” and “Minerals and metals” are first in one out of five places for 3 and 4 pollutants, respectively. This shows that aggregate account 2, “Energy and extractive industries”, to which these two sectors belong, is highly polluting both in terms of its capacity for direct pollution and for the high pollution values of end products. The same is true of aggregate account 5, “Other manufactures”, which is also highly polluting in terms of nitrogen, metals and BDO. Though “Minerals and non metal products” is not highly contaminating in terms of consumption, it does produce significant direct pollution, which means that it pollutes mainly by way of inputs. Furthermore, this account also forms part of aggregate account 2. In Table 4 we may observe that overseas trade again appears as a highly polluting sector and that institutional sectors do not reveal any direct pollution with the sole exception of labour, to which we have assigned household pollution in NO_x, SO_x and CO_2.

To sum up, based on the capacity for direct pollution and the pollution values for different types of consumption, the pollution produced in the Spanish economy is closely associated with production processes and the final goods provided by four aggregate accounts: "Agriculture and food", "Energy and extractive industries", "Other manufactures" and "Overseas trade". As we shall see, this pollution potential is in line with reality.

Table 6 provides a percentage breakdown of the pollution according to the actual components of household expenditure. At first sight, it may seem surprising that aggregate account 7, which includes the productive activities of services that are not potentially polluting, stands out among the pollutants analysed and is always above 27% of the total, except in waste water, the most polluting aggregate account. This is because of the percentage share of services in household expenditure. Services, then, are among the main factors of Spanish pollution not in unit terms but in terms of their large share in final product.

(Insert Table 6)

The situation is similar with the aggregate account "Companies-government". The percentage pollution here is around 16.46%, but household expenditure in this account is almost 28%.

The opposite, however, occurs in aggregate account 1, "Agriculture and food" and "Overseas trade". The former has a share of over 10% in all sources of pollution and the latter a share of around 1.51%. Nevertheless, they represent only 7.35% and 0.60% respectively of total household expenditure. In other words, food spending in general and purchases of imported goods are highly polluting relative in terms for the seven pollutants considered. Furthermore, "Agriculture and food" produces 34.66% of waste water pollution, mainly due to the activities of agro-industry. This is the account producing the highest volume of pollution in waste water. It also holds a significant position in NO_x pollution, mainly due to farming.

If we ignore the account headed "Factors", which is null because households make no expenditure in this are, two out of the six remaining accounts, 6 "Construction" and "Savings-investment" have percentage pollution levels close to expenditure percentages. Consequently, they may be regarded as medium polluters. On the other hand, the four remaining accounts – 2 "Energy and extractive industries", 3 "Chemicals, rubber and plastics", 4 "Metal products, machinery and transport equipment" and 5 "Other manufactures"- have higher average pollution scores than the percentage expenditure on these items. Also, percentage pollution for some of the pollutants is significantly higher than percentage expenditure. Specifically, account 2 is highly polluting in SO_x, largely due to energy generated at power plants. Account 3 pollutes in metals and BDO. Account 4 pollutes in nitrogen, metals and BDO. Finally, account 5, which includes, *inter alia,* in the textile industry, paper, printing and shoe manufacturing, pollutes in nitrogen and BDO.

To end this discussion of the figures shown in Table 6, we may note that the low percentages for the overseas sector, which at no time exceed 2%, does not mean that the pollution embodied in imports is low. The significance of this account is that household expenditure on imported products is low, representing only 0.60% of the total. As a result, the pollution attributable to consumption associated with this expenditure is also low. As we shall see in Table 7, however, pollution imported and embodied via production inputs represents a significant part of the total pollution embodied in the final product of the Spanish economy.

(Insert Table 7)

As may be observed from Table 7, the percentages representing imported pollution are at all times above 20%. Accordingly, we may affirm that the Spanish economy imports a considerable amount of pollution, in all cases representing over one fifth of the total, and in the case of metals one third. Furthermore, in view of figures for imported final goods (see Table 6), there can be no doubt that a great part of imported pollution is associated with production inputs. We may also note in Table 7 that the pollution produced by households is very high in terms of NO_x and CO_2, in both cases representing over 15% of the total. This is a reflection of the significance of household pollution.

Breakdown of pollution by N_i

In order to flesh out the results obtained, let us use the matrices $\mathbf{N}_1$, $\mathbf{N}_2$ and $\mathbf{N}_3$ defined in section 2 to break down pollution of each kind into four main components, $\mathbf{c'N_1y}$, $\mathbf{c'N_2y}$, $\mathbf{c'N_3y}$ y $\mathbf{c'y}$. The relevant percentage values are shown in Table 8, which groups the accounts into four aggregate accounts, two of which are related with production (productive sectors and overseas trade) and two institutional (companies and government, and savings-investment). A complete breakdown of all thirty endogenous accounts is available upon request. The sub-index *s* indicates the relevant aggregate account, while $\mathbf{M_s}$ represents the sub-matrix $\mathbf{M}$ formed by the columns of the aggregate account *s*.

(Insert Table 8)

Taking into account that $\mathbf{c'M_s y_s}$ represents the volume of pollution associated with the household expenditure for the aggregate account *s* and the significance of $\mathbf{N_1 y}$, $\mathbf{c'N_{1s} y_s / c'M_s y_s}$ will be the percentage of pollution generated within the productive accounts (productive sectors and overseas sector) to obtain the inputs consumed in production. In other words, it represents the part of pollution that would be generated in a hypothetical economy where there were no institutional accounts in order to obtain the inputs consumed as a result of expenditure in account *s*. This hypothetical economy is in fact the one described by the conventional input-output model, which includes overseas trade as just another sector.

The percentage values of $\mathbf{c'N_{1s} y_s / c'M_s y_s}$ for the two productive accounts fluctuate between 71.22 % and 50.42%. If we increase these with the values of $\mathbf{c'y_s / c'M_s y_s}$, these percentages rise to between 91.04% and 66.11%. For the total economy, these figures oscillate between 69.48% and 48.72%, with an average of 56.86%. Since this percentage for the total economy $\mathbf{(c'N_1 y + c'y) / c'My}$ is no more than the ratio of the valuation of $\mathbf{y}$ in the hypothetical economy to the total economy, we may affirm that the pollution value of $\mathbf{y}$ obtained from the expanded system is much lower than the real valuation obtained with the SAM model. This in itself justifies the use of models constructed on the basis of SAMs, because the pollution associated with the institutional accounts is arround 43%.

This can also be seen on the basis of $\mathbf{N_{2s}}$, and more specifically $\mathbf{c'N_{2s} y_s}$, which represents the pollution generated in the productive sectors of the hypothetical economy to cover expenditures induced directly in institutional accounts by the productive effects of the household demand for goods. Consequently, $\mathbf{c'N_{2s} y_s}$ reflects the pollution induced by primary feedback via the institutional accounts, while $\mathbf{c'N_{2s} y_s / c'M_s y_s}$ is the percentage measure.

As can be seen from Table 8, the highest figures for $\mathbf{c'N_{2s} y_s / c'M_s y_s}$ are obtained in the institutional sectors. For the total economy, these values fluctuate between 9.54% and 19.73%, reflecting a part of the 43% share of institutional factors. As we may observe, $\mathbf{c'N_{3s} y_s / c'M_s y_s}$,, which reflects the remaining share for these factors, varies between 20.98% and 31.90% depending on the pollutant. Once again this confirms the utility of working with SAM-based models.

The third ratio in Table 8, $\mathbf{c'y_s / c'M_s y_s}$, measures the percentage pollution embodied in net product as compared to total pollution. In a way, this is a measure of the efficiency of household expenditure in this account. In the productive sectors, $\mathbf{c'y_s / c'M_s y_s}$ in no case exceeds 18% and, focusing on the totals, we find that it oscillates between 9.71% and 13.79%. This tells us that the necessary pollution is always over seven times the level attributable to the net final product. In other words, productive efficiency in relation to pollution is very low, and we should perhaps ask whether it is not excessively so taking into account, for example, that efficiencies in the physical processes involved in power generation lie between 20% and 30%.

Footprints of the Spanish economy

The title of this paper refers to footprints, but we have so far not obtained any *per capita* data to indicate the pollution impact of an individual in the Spanish economy. Nevertheless, such data can easily be obtained from the information already presented. Multiplying the pollution values for each possible instance of household consumption, we may sum the products and divide the results by the population of Spain in 1999 (40,202,160 inhabitants according to the Spanish Statistical Institute) to obtain Table 9, which show *per capita* impacts or footprints.

(Insert Table 9)

The last column of Table 9 shows the *per capita* value added of the Spanish economy. The total figures in the table are highly significant and provide a clear view of the impact every Spanish citizen makes on the environment. Let us consider the case of waste water. If we assume that direct consumption of water per person per day is around 50 litres, providing the comfort of a high standard of living, then annual consumption will be 18.25 m^3 per person. Thus, the footprint of waste water is over 16 times direct consumption. Another way of looking at this footprint is to image how much waste water is produced per square meter of the territory of Spain, which is approximately 500,000 km^2. The waste water produced by all the citizens of Spain is 12,116 million m^3, which represents over 24 litres per square meter, a layer some 25 cm deep which would cover the whole of the Spanish landmass. This figure may be compared with rainfall for 1999 in the country's river basins. The figures are given in Table 10.

(Insert Table 10)

The figures for the CO_2 footprint are also surprising. This footprint is over 9 tonnes *per capita* released into the atmosphere by every Spanish citizen. For an average volume of 80 kilograms, this means that each citizen emits over 118 times his/her own weight per year, or that we release over 26 kilos per day.

If we consider the five highest figures for each column of Table 9, the five accounts with the highest pollution in absolute terms (shown in bold type), we find that four accounts stand out. These are “Food products, beverages and tobacco”, “Catering and restaurants”, “Government” and “Savings-investment”, which are the leading polluters for the seven kinds of pollution. This is essentially because of the high level of expenditure these accounts represent within the households account. Unit expenditure was analysed above. This leads to the reflection that food in general (food, beverages, restaurants and catering) is one of the main sources of pollution. In this light, we may perhaps consider whether we should not change our consumption patterns in order to improve the environment, and what effect such changes would have. Finally, Table 9 shows the relationship between the generation of value added and pollution. The accounts “Retailing” and “Property activities” generate significant value added, though their contribution to the footprint is small. In contrast, the accounts “Food products, beverages and tobacco”, “Catering and restaurants”, “Government” and “Savings-investment” generate significant value added but at the same large amounts of pollution of all kinds. There can be no doubt that these accounts should be studied in detail for the purpose of designing any policy aimed at reducing pollution.

Unquestionably, not all households have the same footprints, and these depend on income levels. In order to estimate the impact of income on pollution, we have classified households with active workers into seven groups based on data provided by the Spanish Statistical Institute’s Active Population Survey. The group structure is as follows:

Group 1	Workers earning less that € 9,375.8 per annum
Group 2	Workers earning between € 9,375.9 and € 14,063.7 per annum
Group 3	Workers earning between € 14,063.8 and € 18,751.6 per annum
Group 4	Workers earning between € 18,751.7 and € 23,439.5 per annum
Group 5	Workers earning between € 23,439.6 and € 28,127.4 per annum
Group 6	Workers earning between € 28,127.5 and € 46,879 per annum
Group 7	Workers earning over € 46,879 per annum

Table 11 shows the footprints for these groups on the assumption that each incurs the same expenditure. According to the SAM used, the average *per capita* household expenditure is € 13,111. We then add an approximate index relating *per capita* income between households based on Group 4. The same data are presented in Table 12, but in this case using their true expenditures.

(Insert Tables 11 and 12)

As shown in Table 12, the footprints depend crucially on income. Thus, all pollutants increase as the group's income rises, while the average values for the economy as a whole are similar to those found for group 4, which comprises households with an annual income of around € 20,000. Consequently, wealthier citizens tend to pollute more. Nevertheless, the snapshot provided by Table 11 differs, except as regards CO_2, with the lower income groups polluting more. This should be borne in mind in the formulation of policies aimed at reducing pollution.

4. Conclusions

In this paper we have presented the key aspects of polluting behaviour by Spanish households, obtaining estimates of pollution for waste water, nitrogen, metals, BDO, BDO, NO_x, SO_x and CO_2, enabling us to calculate the corresponding *per capita* pollution, which provides an approximation to the ecological footprint of the Spanish population.

Specifically, the analysis reveals that pollution in Spain is closely linked to food production, energy, extractive industries and paper manufacturing. We have shown that services, taken as a whole, are major polluters, though this is due to the volume of household expenditure they represent rather than their pollution potential as such. We also show that the Spanish economy avoids a great deal of pollution by importing inputs, which pollute where they are produced.

Also, by associating the estimated footprints with household incomes, we have found that these are strongly dependent on income levels and rise in line with them. Nevertheless, where overall income is the same, poorer households are more polluting than richer ones.

We have obtained these results working with a model based on a social accounting matrix rather than using the input-output analysis framework. We have shown that the quantification of real pollution generated in the economy is the same in both models, although the SAM model provides a more detailed analysis of relationships between households and other economic sectors and institutions, as well as throwing light on their role in the generation and transfer of pollution. This reveals the crucial role played by household demand and expenditure in atmospheric and water pollution.

The expansion of the input-output framework to the SAM analysis also highlights the need for detailed studies of how to include pollution items that are left out in the standard inter-sector analysis in the model. Nevertheless, we have been able to make reasonable assumptions for the inclusion of imported and household pollution, although there can be no doubt that this can only be regarded as an initial approximation to the problem and that better statistical information would allow us to use other criteria, which would improve results.

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Table 1: SAM model

	(1)	(2)	(3)	(4)	(5)	(6)	Total
1. Productive sectors	$\mathbf{X}_{11}$	$\mathbf{X}_{12}$	**0**	$\mathbf{X}_{14}$	$\mathbf{X}_{15}$	$\mathbf{X}_{16}$	$\mathbf{x}_1$
2. Overseas trade	$\mathbf{X}_{21}$	**0**	$\mathbf{X}_{23}$	$\mathbf{X}_{24}$	$\mathbf{X}_{25}$	$\mathbf{X}_{26}$	$\mathbf{x}_2$
3. Factors	$\mathbf{X}_{31}$	$\mathbf{X}_{32}$	**0**	**0**	**0**	**0**	$\mathbf{x}_3$
4. Companies-Government	$\mathbf{X}_{41}$	$\mathbf{X}_{42}$	$\mathbf{X}_{43}$	$\mathbf{X}_{44}$	**0**	$\mathbf{X}_{46}$	$\mathbf{x}_4$
5. Savings-investment	**0**	**0**	**0**	$\mathbf{X}_{54}$	**0**	$\mathbf{X}_{56}$	$\mathbf{x}_5$
6. Households	**0**	$\mathbf{X}_{62}$	$\mathbf{X}_{63}$	$\mathbf{X}_{64}$	**0**	$\mathbf{X}_{66}$	$\mathbf{x}_6$
Total	$\mathbf{x}_1$	$\mathbf{x}_2$	$\mathbf{x}_3$	$\mathbf{x}_4$	$\mathbf{x}_5$	$\mathbf{x}_6$	

Table 2: Composition of the 12 aggregate accounts

AGGREGATE ACCOUNT	SAM ACCOUNT
Aggregate account 1: Agriculture and food	Agriculture, forestry and fish farming
	Food products, beverages and tobacco
Aggregate account 2: Energy and extractive industries	Energy products
	Water
	Minerals and metals
	Minerals and non metal products
Aggregate account 3: Chemicals, rubber and plastics	Chemicals
	Rubber, plastics and other manufactures
Aggregate account 4: Metal products, machinery and transport equipment	Metal products and machinery
	Transport equipment
Aggregate account 5: Other manufactures	Textiles, leather and shoes
	Paper, paper articles and printed matter
	Wood, cork and wooden furniture
Aggregate account 6: Construction	Construction and engineering
Aggregate account 7: Services	Recycling and repairs
	Retailing
	Catering and restaurants
	Transport and communications
	Banking and insurance
	Property activities
	Education
	Health
	Government and other services
Aggregate account 8: Overseas trade	European Union
	Rest of the world
Aggregate account 9: Factors	Labour
	Capital
Aggregate account 10: Companies-Government	Companies
	Government
Aggregate account 11: Savings-investment	Savings-investment
Aggregate account 12: Households	Households

Table 3: 1999 Social Accounting Matrix for the Spanish Economy (millions of €)

	Aggregate account 1	Aggregate account 2	Aggregate account 3	Aggregate account 4	Aggregate account 5	Aggregate account 6	Aggregate account 7	European Union	Rest of the world	Labour	Capital	Companies	Govern ment	Savings-investment	Households	Total jobs
Aggregate account 1	38.862	20	457	11	1.724	329	16.508	16.127	3.754	0	0	0	0	906	38.724	117.423
Aggregate account 2	2.939	16.709	2.697	5.589	1.085	13.987	11.162	5.095	3.134	0	0	0	0	343	11.000	73.741
Aggregate account 3	4.116	1.205	16.306	9.286	3.174	2.358	6.212	13.164	5.158	0	0	0	1.173	3.915	12.076	78.144
Aggregate account 4	2.097	3.224	2.593	50.579	1.812	9.429	10.079	50.949	15.287	0	0	0	34	39.325	18.715	204.122
Aggregate account 5	2.258	955	2.207	2.175	18.724	2.600	9.693	8.391	3.596	0	0	0	0	446	17.850	68.894
Aggregate account 1	212	412	126	432	168	13.533	13.188	4	4	0	0	0	0	72.368	2.416	102.864
Aggregate account 7	15.033	10.742	10.554	22.715	8.941	15.840	122.739	20.747	10.135	0	0	0	97.378	21.645	234.204	590.673
European Union	9.840	3.658	18.473	56.598	8.961	8	11.172	0	0	265	0	15.122	6.081	-1.528	2.155	130.806
Rest of the world	8.083	10.341	5.811	17.087	5.174	12	7.429	0	0	340	0	3.099	1.510	-10.207	985	49.664
Labour	12.315	9.005	11.302	25.956	12.549	27.562	184.297	302	275	0	0	0	0	0	0	283.563
Capital	22.690	14.867	5.363	10.202	5.109	12.436	154.400			0	0	0	0	0	0	225.067
Companies	0	0	0	0	0	0	0	8.296	5.454	0	97.742	39.248	14.922	0	29.873	195.535
Government	-1.023	2.602	2.256	3.493	1.473	4.770	43.795	4.299	210	0	8.383	23.974	62.793	0	117.136	274.161
Savings-investment	0	0	0	0	0		0	0	0	0	0	69.155	16.121	0	41.937	127.213
Households	0	0	0	0	0	0	0	3.432	2.655	282.958	118.942	44.937	74.148	0	20.817	547.890
Total resources	117.423	73.741	78.144	204.122	68.894	102.864	590.673	130.806	49.664	283.563	225.067	195.535	274.161	127.213	547.890	1.833.899

Aggregate account 1: Agriculture and food; **Aggregate account 2:** Energy and extractive industries; **Aggregate account 3:** Chemicals, rubber and plastics; **Aggregate account 4:** Metal products, machinery and transport equipment; **Aggregate account 5:** Other manufactures; **Aggregate account 6:** Construction; **Aggregate account 7:** Services

Table 4: Direct pollution per million euros of household expenditure

Aggregate account	**Account**	**Waste water** ('000 m^2)	**Nitrogen** ('000 tonnes)	**Metals** ('000 tonnes)	**BDO** ('000 tonnes)	**NO_x** (tonnes)	**SO_x** (tonnes)	**CO_2** ('000 tonnes)	**Resources** (millions of euros)
Aggregate account 1	**Agriculture and fish farming**	**173,64**	0,00	0,00	0,00	**4,73**	0,39	0,29	44.683
	Food products, beverages and tobacco	0,90	0,03	0,03	0,33	0,44	0,03	0,06	72.740
Aggregate account 2	**Energy products**	1,31	0,02	0,04	0,11	**7,69**	**27,60**	**2,33**	44.108
	Water	0,53	0,01	0,03	0,05	0,25	0,73	0,14	3.317
	Minerals and metals	**23,80**	**0,23**	**0,46**	**2,65**	1,34	0,03	0,11	3.724
	Minerals and non metal products	0,99	0,02	0,02	0,31	**4,75**	**5,66**	**1,79**	22.592
Aggregate account 3	**Chemicals**	**7,90**	**0,18**	**1,52**	**2,99**	0,56	**1,26**	0,25	46.519
	Rubber, plastics and other manufactures	4,31	0,06	0,26	**1,58**	0,04	0,09	0,02	31.625
Aggregate account 4	**Metal products and machinery**	0,25	0,01	0,01	0,05	0,30	0,58	0,12	127.390
	Transport equipment	0,56	0,01	0,01	0,15	0,04	0,06	0,01	76.732
Aggregate account 5	**Textiles, leather and shoes**	2,97	**0,13**	0,04	1,38	0,22	0,23	0,06	32.474
	Paper, paper articles and printed matter	7,66	**0,39**	**0,68**	**2,66**	0,33	0,63	0,20	26.895
	Wood, cork and wooden furniture	3,89	**0,19**	0,04	**1,54**	0,84	0,34	0,16	9.525
Aggregate account 6	**Construction and engineering**	0,13	0,00	0,00	0,00	0,20	0,01	0,02	102.864
Aggregate account 7	**Recycling and repairs**	0,60	0,00	0,00	0,00	**4,42**	0,08	**0,31**	962
	Retailing	0,60	0,00	0,00	0,00	0,18	0,06	0,03	102.392
	Catering and restaurants	0,60	0,00	0,00	0,00	0,04	0,05	0,02	74.825
	Transport and communications	0,60	0,00	0,00	0,00	2,12	0,40	0,27	84.278
	Banking and insurance	0,60	0,00	0,00	0,00	0,00	0,02	0,01	43.937
	Property activities	0,60	0,00	0,00	0,00	0,01	0,03	0,01	57.908
	Education (private and public)	0,60	0,00	0,00	0,00	0,01	0,06	0,02	33.370
	Health (private and public)	0,60	0,00	0,00	0,00	0,01	0,07	0,02	44.942
	Government and other services	0,60	0,00	0,00	0,00	0,05	0,04	0,01	148.059
Overseas trade	**European Union**	**11,91**	0,08	**0,31**	0,94	1,30	**2,29**	**0,33**	130.806
	Rest of the world	**25,78**	0,08	**0,30**	1,01	**3,51**	**8,52**	**0,89**	49.664
Factors	**Labour**	0,00	0,00	0,00	0,00	1,15	0,12	0,21	283.563
	Capital	0,00	0,00	0,00	0,00	0,00	0,00	0,00	225.067
Companies-Government	**Companies**	0,00	0,00	0,00	0,00	0,00	0,00	0,00	195.535
	Government	0,00	0,00	0,00	0,00	0,00	0,00	0,00	274.161
Savings-investment	**Savings-investment**	0,00	0,00	0,00	0,00	0,00	0,00	0,00	127.213

Table 5: Backward linkage or pollution values per million euros of household expenditure

Aggregate account	Account	**Waste water** ('000 m^2)	**Nitrogen** ('000 tonnes)	**Metals** ('000 tonnes)	**BDO** ('000 tonnes)	**NO_x** (tonnes)	**SO_x** (tonnes)	**CO_2** ('000 tonnes)	**Households** (millions of euros)
Aggregate account 1	**Agriculture and fish farming**	**214,99**	0,11	0,42	1,30	**8,68**	5,82	1,12	5.733
	Food products, beverages and tobacco	**89,94**	0,16	0,49	1,84	6,18	6,18	1,09	32.992
Aggregate account 2	**Energy products**	27,14	0,14	0,48	1,54	**14,42**	**44,14**	**4,11**	9.138
	Water	11,94	0,08	0,31	0,88	3,55	7,24	0,98	1.443
	Minerals and metals	**50,36**	**0,35**	**0,96**	**4,21**	6,51	**9,70**	1,37	0
	Minerals and non metal products	19,89	0,13	0,41	1,65	9,06	12,61	2,84	419
Aggregate account 3	**Chemicals**	41,52	0,37	2,35	5,37	5,49	9,51	1,45	5.068
	Rubber, plastics and other manufactures	33,50	0,24	**1,08**	**3,91**	4,35	6,98	1,05	7.008
Aggregate account 4	**Metal products and machinery**	31,94	0,16	0,60	1,92	5,17	8,36	1,28	5.586
	Transport equipment	34,95	0,18	0,67	2,29	4,89	7,65	1,17	13.129
Aggregate account 5	**Textiles, leather and shoes**	37,61	**0,31**	0,64	**3,60**	4,75	7,20	1,10	12.924
	Paper, paper articles and printed matter	35,35	**0,65**	**1,37**	**5,02**	4,17	6,26	1,12	4.667
	Wood, cork and wooden furniture	32,59	**0,36**	0,48	3,35	4,95	6,01	1,08	259
Aggregate account 6	**Construction and engineering**	13,21	0,08	0,26	0,92	3,65	4,43	0,91	2.416
Aggregate account 7	**Recycling and repairs**	17,43	0,10	0,33	1,10	**7,85**	5,42	1,13	0
	Retailing	9,61	0,05	0,18	0,60	2,40	2,99	0,54	58.341
	Catering and restaurants	28,16	0,06	0,22	0,76	2,86	3,44	0,59	64.537
	Transport and communications	12,21	0,06	0,21	0,68	5,03	4,69	0,93	18.063
	Banking and insurance	8,59	0,04	0,14	0,48	2,07	2,38	0,46	8.531
	Property activities	8,82	0,05	0,16	0,54	1,73	2,26	0,42	38.037
	Education (private and public)	5,13	0,03	0,09	0,31	1,75	1,75	0,39	7.486
	Health (private and public)	10,00	0,06	0,26	0,73	2,14	2,63	0,50	13.966
	Government and other services	11,74	0,07	0,22	0,73	2,48	3,15	0,56	25.243
Overseas trade	**European Union**	**54,41**	0,24	**0,93**	2,94	6,18	9,39	**1,43**	2.155
	Rest of the world	**57,03**	0,24	0,88	2,91	**8,14**	**15,73**	**1,99**	985
Factors	**Labour**	0,12	0,00	0,00	0,01	1,16	0,14	0,21	0
	Capital	6,92	0,04	0,13	0,43	1,19	1,63	0,29	0
Companies-Government	**Companies**	15,16	0,08	0,28	0,93	2,60	3,56	0,62	29.873
	Government	9,07	0,05	0,18	0,58	1,75	2,28	0,41	117.136
Savings-investment	**Savings-investment**	16,66	0,09	0,33	1,13	3,54	4,50	0,87	41.937

Table 6: Percentage pollution per components of household expenditure

	Aggregate account 1	Aggregate account 2	Aggregate account 3	Aggregate account 4	Aggregate account 5	Aggregate account 6	Aggregate account 7	Overseas trade	Factors	Companies-Government	Savings-investment	Total
Household expenditure	7,35	2,09	2,29	3,55	3,39	0,46	44,43	0,60	0,00	27,89	7,96	100,00
Waste water	34,66	2,26	3,67	5,26	5,44	0,26	28,73	1,43	0,00	12,51	5,77	100,00
Nitrogen	12,38	3,01	7,50	7,01	15,16	0,39	27,68	1,59	0,00	17,03	8,26	100,00
Metals	11,41	3,08	11,96	7,48	9,04	0,38	28,03	1,76	0,00	18,40	8,44	100,00
BDO	12,26	2,88	9,81	7,34	12,71	0,40	27,18	1,65	0,00	17,22	8,55	100,00
NO_x	14,98	8,31	3,44	5,50	4,85	0,52	35,69	1,26	0,00	16,68	8,78	100,00
SO_x	10,10	17,84	4,13	6,26	5,27	0,46	30,53	1,52	0,00	15,88	8,02	100,00
CO_2	11,17	10,56	3,87	5,91	5,19	0,58	34,33	1,33	0,00	17,49	9,57	100,00
Average % pollution	15,28	6,85	6,34	6,39	8,24	0,43	30,31	1,51	0,00	16,46	8,20	100,00

Table 7: Direct pollution from households and imports

	Waste water ('000 m^3)	**Nitrogen** ('000 tonnes)	**Metal** ('000 tonnes)	**BDO** ('000 tonnes)	**NO_x** (tonnes)	**SO_x** (tonnes)	**CO_2** ('000 tonnes)
Productive processes	9.278.073	33.110	106.844	384.289	1.022.903	1.593.826	233.885
% in productive processes	76,58	70,09	65,66	69,03	60,42	67,83	61,53
Households	0	0	0	0	325.873	32.859	59.227
% Households	0,00	0,00	0,00	0,00	19,25	1,40	15,58
Imports	2.838.105	14.132	55.869	172.438	344.229	723.189	87.007
% Imported	23,42	29,91	34,34	30,97	20,33	30,78	22,89
Total	12.116.177	47.241	162.713	556.726	1.693.004	2.349.874	380.119

Table 8: Component percentages for each type of pollution

Pollutant	Ratio	Productive sectors	Overseas trade	Companies and government	Savings-investment	TOTAL
	$c'N_{1s}y_s/c'M_sy_s$	71,22	61,60	0,00	0,00	58,07
	$c'N_{2s}y_s/c'M_sy_s$	0,00	0,00	40,39	77,83	9,54
Waste water	$c'N_{3s}y_s/c'M_sy_s$	15,09	8,96	59,61	22,17	20,98
	$c'y_s/c'M_sy_s$	13,69	29,44	0,00	0,00	11,41
	Total	100,00	100,00	100,00	100,00	100,00
	$c'N_{1s}y_s/c'M_sy_s$	60,05	56,54	0,00	0,00	44,81
	$c'N_{2s}y_s/c'M_sy_s$	0,00	0,00	39,90	79,56	13,36
Nitrogen	$c'N_{3s}y_s/c'M_sy_s$	21,81	10,59	60,10	20,44	28,04
	$c'y_s/c'M_sy_s$	18,14	32,86	0,00	0,00	13,79
	Total	100,00	100,00	100,00	100,00	100,00
	$c'N_{1s}y_s/c'M_sy_s$	63,34	55,94	0,00	0,00	46,20
	$c'N_{2s}y_s/c'M_sy_s$	0,00	0,00	41,12	78,59	14,20
Metals	$c'N_{3s}y_s/c'M_sy_s$	23,90	10,23	58,88	21,41	29,89
	$c'y_s/c'M_sy_s$	12,76	33,83	0,00	0,00	9,71
	Total	100,00	100,00	100,00	100,00	100,00
	$c'N_{1s}y_s/c'M_sy_s$	59,81	56,81	0,00	0,00	44,35
	$c'N_{2s}y_s/c'M_sy_s$	0,00	0,00	39,20	79,79	13,57
BDO	$c'N_{3s}y_s/c'M_sy_s$	22,54	10,47	60,80	20,21	28,73
	$c'y_s/c'M_sy_s$	17,65	32,72	0,00	0,00	13,35
	Total	100,00	100,00	100,00	100,00	100,00
	$c'N_{1s}y_s/c'M_sy_s$	51,77	50,92	0,00	0,00	38,59
	$c'N_{2s}y_s/c'M_sy_s$	13,06	6,99	26,42	64,56	19,73
NO_x	$c'N_{3s}y_s/c'M_sy_s$	20,83	12,78	73,58	35,44	30,80
	$c'y_s/c'M_sy_s$	14,34	29,31	0,00	0,00	10,88
	Total	100,00	100,00	100,00	100,00	100,00
	$c'N_{1s}y_s/c'M_sy_s$	62,33	51,88	0,00	0,00	47,28
	$c'N_{2s}y_s/c'M_sy_s$	0,93	0,42	38,07	78,97	13,08
SO_x	$c'N_{3s}y_s/c'M_sy_s$	19,99	10,37	61,93	21,03	26,59
	$c'y_s/c'M_sy_s$	16,74	37,33	0,00	0,00	10,88
	Total	100,00	100,00	100,00	100,00	97,82
	$c'N_{1s}y_s/c'M_sy_s$	52,21	50,42	0,00	0,00	38,06
	$c'N_{2s}y_s/c'M_sy_s$	10,82	5,37	28,12	69,43	19,38
CO_2	$c'N_{3s}y_s/c'M_sy_s$	22,66	12,91	71,88	30,57	31,90
	$c'y_s/c'M_sy_s$	14,30	31,30	0,00	0,00	10,66
	Total	100,00	100,00	100,00	100,00	100,00

Table 9: Annual footprints for the Spanish economy in 1999 and breakdown by accounts generating pollution

Aggregate account	Account	Waste water (m^3)	Nitrogen (Kg.)	Metals (Kg.)	BDO (Kg.)	NO_x (Kg.)	SO_x (Kg.)	CO_2 (Kg.)	Value added (euros)
Aggregate account 1	Agriculture, forestry and fish farming	**30,7**	15,1	59,7	185,9	1,2	0,8	159,6	162,9
	Food products, beverages and tobacco	**73,8**	**130,4**	**402,2**	**1.511,6**	**5,1**	**5,1**	**896,7**	901,5
Aggregate account 2	Energy products	6,2	31,1	109,3	350,3	3,3	**10,0**	**933,4**	245,6
	Water	0,4	2,9	11,1	31,8	0,1	0,3	35,1	39,3
	Minerals and metals	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Minerals and non metal products	0,2	1,4	4,2	17,2	0,1	0,1	29,6	11,0
Aggregate account 3	Chemicals	5,2	46,8	**296,2**	677,2	0,7	1,2	182,2	128,5
	Rubber, plastics and other manufactures	5,8	41,3	187,8	682,0	0,8	1,2	183,8	179,2
Aggregate account 4	Metal products and machinery	4,4	22,7	82,8	267,4	0,7	1,2	177,6	141,2
	Transport equipment	11,4	59,7	220,0	749,0	1,6	2,5	381,1	331,6
Aggregate account 5	Textiles, leather and shoes	12,1	**100,6**	204,2	**1.156,1**	1,5	2,3	354,2	329,8
	Paper, paper articles and printed matter	4,1	75,1	158,8	582,5	0,5	0,7	130,0	121,6
	Wood, cork and wooden furniture	0,2	2,3	3,1	21,6	0,0	0,0	7,0	6,7
Aggregate account 6	Construction and engineering	0,8	4,6	15,4	55,1	0,2	0,3	54,6	63,2
Aggregate account 7	Recycling and repairs	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Retailing	13,9	75,0	263,0	866,5	**3,5**	4,3	779,5	**1.603,0**
	Catering and restaurants	**45,2**	**103,9**	**349,7**	**1.212,9**	**4,6**	**5,5**	**950,4**	**1.818,1**
	Transport and communications	5,5	26,4	92,7	307,6	2,3	2,1	419,4	489,6
	Banking and insurance	1,8	9,3	30,6	102,1	0,4	0,5	97,7	216,2
	Property activities	8,3	42,8	152,4	508,0	1,6	2,1	399,0	**1.110,8**
	Education (private and public)	1,0	5,5	17,0	57,5	0,3	0,3	72,5	187,7
	Health (private and public)	3,5	20,2	91,6	252,2	0,7	0,9	173,8	358,5
	Government and other services	7,4	42,2	137,5	457,4	1,6	2,0	353,5	648,7
Overseas trade	European Union	2,9	12,8	49,7	157,6	0,3	0,5	76,9	52,6
	Rest of the world	1,4	5,9	21,6	71,2	0,2	0,4	48,8	23,2
Factors	Labour	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Capital	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Companies-Government	Companies	11,3	56,9	208,4	693,4	1,9	2,6	464,2	505,3
	Government	**26,4**	**143,2**	**536,5**	**1.690,6**	**5,1**	**6,6**	**1.189,9**	**1.873,6**
Savings-investment	Savings-investment	**17,4**	**97,0**	**341,7**	**1.183,8**	**3,7**	**4,7**	**904,8**	**1.102,2**
	Total or footprint	*301,4*	*1.175,1*	*4.047,4*	*13.848,2*	*42,1*	*58,5*	*9.455,2*	*12.651,8*

Table 10: Rainfall (l./m²) in mainland Spain, 1999

1999	Total	January	February	March	April	May	June	July	August	September	October	November	December
Mainland Spain	628	47	31	61	53	53	24	26	20	85	127	46	57
North and Northwest	1.451	119	101	160	146	118	33	26	53	189	171	143	193
Duero River	578	48	19	36	54	62	22	28	27	80	127	26	49
Tagus River	568	37	19	39	49	55	24	17	10	74	183	23	40
Guadiana River	451	32	14	47	33	35	17	5	3	57	146	17	46
Guadalquivir River	472	39	24	51	22	16	6	1	2	54	175	26	55
South	424	51	43	59	14	8	2	1	0	31	125	47	44
Segura River	330	19	44	52	11	13	8	8	6	45	71	26	27
Júcar River	417	20	17	69	32	22	25	31	11	70	70	29	22
Ebro River	639	39	28	61	62	70	42	64	31	93	61	59	32
Western Pyrenees	686	71	3	24	50	84	37	46	41	131	93	95	12

Table 11: Footprints for different groups of households at a common average income

Type household	Waste water (m³)	Nitrogen (Kg.)	Metals (Kg.)	BDO (Kg.)	NO_x (Kg.)	SO_x (Kg.)	CO_2 (Kg.)	Income index
Group 1	462,6	1.329,3	4.514,7	15.300,4	45,2	68,5	9.125,1	0,40
Group 2	399,3	1.281,1	4.328,2	14.792,4	43,3	64,4	9.079,4	0,55
Group 3	337,4	1.200,4	4.060,8	13.916,7	41,9	60,3	9.098,4	0,88
Group 4	283,0	1.158,6	3.986,2	13.666,3	41,2	57,5	9.352,2	1,00
Group 5	259,1	1.133,0	3.941,5	13.492,1	40,6	55,1	9.352,5	1,23
Group 6	229,1	1.087,6	3.797,1	12.970,9	39,8	53,0	9.338,7	1,75
Group 7	198,5	1.049,1	3.714,0	12.644,9	38,9	50,3	9.325,7	2,84

Table 12: Footprints for different groups of households

Type household	Waste water (m³)	Nitrogen (Kg.)	Metals (Kg.)	BDO (Kg.)	NO_x (Kg.)	SO_x (Kg.)	CO_2 (Kg.)
Group 1	185,0	531,7	1.805,9	6.120,1	18,1	27,4	3.650,0
Group 2	219,6	704,6	2.380,5	8.135,8	23,8	35,4	4.993,7
Group 3	295,2	1.050,4	3.553,2	12.177,1	36,6	52,8	7.961,1
Group 4	283,0	1.158,6	3.986,2	13.666,3	41,2	57,5	9.352,2
Group 5	317,4	1.387,9	4.828,4	16.527,8	49,7	67,5	11.456,8
Group 6	400,8	1.903,3	6.645,0	22.699,0	69,6	92,7	16.342,8
Group 7	564,3	2.982,4	10.558,3	35.947,6	110,5	143,1	26.511,5