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## Regional productive structure and water pollution: An analysis using the input-output model

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**REGIONAL PRODUCTIVE STRUCTURE AND WATER POLLUTION:  
AN ANALYSIS USING THE INPUT-OUTPUT MODEL**

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**Abstract**

The objective of this paper is to carry out an in-depth study of the structural relationships between economic and environmental variables with particular reference to the water resource in the Ebro Valley (Spain). To that end, we employ the concepts and indicators derived from input-output analysis.

Thus, we present a methodology to obtain the key sectors in water returns and pollution, the forward and backward linkage, the elasticities and the trade-offs between water pollution with the economic variables of income and employment. We obtain the generating sub-systems of water pollution and refine its traditional indicators. This supposes an advance, in that it allows the traditional table to be orientated towards a new approach, one that is the more appropriate for the economic-environmental relationships.

The empirical application is made individually for the four regions of the Ebro Valley, as well as for an integrated input-output table for the complete Valley, with our aim being to describe the inter-sectoral productive relations and their impact on water.

**Keywords:** Water economics, water pollution, environmental input-output tables.

# **REGIONAL PRODUCTIVE STRUCTURE AND WATER POLLUTION: AN ANALYSIS USING THE INPUT-OUTPUT MODEL**

## **1. Introduction**

Article 38 of the Water Law (1984) states the general objectives of water planning as being “to achieve the greatest satisfaction of the demands on water and to balance and harmonise regional and sectorial development, increasing the availability of the resource, protecting its quality, saving on its use and economising its uses in harmony with the environment and the other natural resources”. Logically, achieving this objective, or any other in this line, is necessarily linked to a deeper knowledge of the structural relationships between economic activities and the environmental conditions in which these are carried out.

In Spain, interest in water management has been strengthened by the fact that we are dealing with an apparently scarce resource and by the loss of water quality due to pollution of both natural and subterranean water. The growing fear that many areas will suffer a scarcity of water has led us to consider its re-use in order to satisfy the numerous necessities that it has to meet, within what we can describe as a circulatory model.

We can often see how the scarcity of water in many areas does not refer to a physical scarcity of the resource, whatever its quality, but rather to the scarcity of a determined quality of water for certain specific uses. This form of scarcity is due both to the polluting effects of intensive agriculture, involving the massive use of harmful fertilisers, as well as to other factors, from amongst which we can place emphasis on the increase and concentration of the population in urban centres, growing industrialisation and centralisation in industrial areas and the ever-increasing complexity of productive processes.

Against this background, the circulatory model shows us how each agent or user is, in turn, the supplier of water for subsequent uses. Thus, each productive sector, or each agent, is responsible for the alterations that its activity causes (directly or indirectly) to the quality of the resource. It is therefore necessary to define the levels of responsibility of each user so that we can draw closer to the nucleus of the problem of water pollution.

In this paper we present a methodology for the treatment of water pollution that results from a determined productive structure, in our particular case, that found in the Ebro Valley. Emphasis is placed on the framework of economic relationships within the region from a

macro-economic point of view, one which considers both the intersectorial relationships, as well as the dependencies between groups and productive processes. The application of the input-output methodology allows us to identify the key sectors in the water polluting process within the economy, that is to say, sectors or activities which require a very detailed analysis and follow-up when determining policies aimed at regional development and environmental management.

The rest of the paper is organised as follows. Section 2 is devoted to the antecedents and the theoretical framework upon which our study is based, as well as to the initial assumptions. In Section 3 we define the characteristics of the model and the peculiarities of the vectors and matrices employed. The input-output methodology described in this Section allows us to draw closer to the problem of returns and water pollution in the productive structure of the Ebro Valley. The use of Leontief's inverse matrix allows us to obtain the different forward and backward linkages and thereby to identify the key sectors with respect to returns and water pollution. These sectors are clearly of great interest when formulating realistic proposals for improving the quality of the resource in the area. In Section 4 we search for better indicators of the relationship between productive activities and water, concentrating on obtaining the so-called trade-offs and on the analysis of the elasticities. In Section 5 we present some results of the application of the water consumers and pollution generating subsystems technique. Section 6 closes the paper with a review of the most relevant conclusions.

## **2. Antecedents, sources and initial assumptions**

The problem of the environment in general, and of the pollution of the environment in particular, has led to the creation of a significant body of economic literature that seeks to explain the relationships between economic activity and the environment. Alongside the theoretical efforts, important advances have been made in developing models which act as a base for the study of these relationships. In this context the input-output analysis has emerged as a method that explains the relationships within a productive system, considering this system in its totality and taking into account the interrelationships between the different productive sectors in order to obtain the final output. In the environmental field, the first attempt to extend the traditional input-output models to encompass the study of environmental pollution was made on the part of Leontief himself, when in 1970 he proposed an integrated method to consider productive activities and their environmental effects in the functioning of the economy.

The basis of environmental input-output analysis is found in the input-output tables. These tables describe the relationships between the sectors of an economy, taking into account the resource flows between sectors, the final products and the inputs or resources used to produce them. The variables are generally expressed in monetary terms. Its extension to the environmental field concentrates on adding various additional tables to the traditional economic tables in order to describe the resource flows obtained from the environment and the different types of pollution that appear as a consequence of the productive activities. Specifically, in 1970 Leontief added three tables to the original goods by industry tables, namely the primary environmental input tables, the pollution tables (as outputs) and the table of internal relationships between antipolluting sectors. This initial proposal carried significant problems with it: first, the theoretical, involving a break with the assumption of the goods by industry structure, by assuming that each sector produces at least two types of outputs, the economic and the residual, as well as problems of aggregation caused by different units of valuation of the output; secondly, the operative, that is to say, the lack of data for the matrices of relationships between environmental sectors. Victor's extended table assumes these problems and proposes an industry by industry model to which two relationship tables are added, in the form of satellite accounts, one of primary outputs and the other of waste products introduced into the environment. Victor himself comments on the need to evaluate the resources and economic and physical output in different units in order to achieve a better description of the processes in which price variation have no influence (Victor, 1972).

Works that have employed the input-output technique for environmental analysis have usually chosen to adopt what Pajuelo has called a "partial equilibrium approach", that is to say, to consider only those flows that move from the economic to the environmental medium. In this regard, see the interesting works of Pajuelo (1980) a pioneer in Spain in the analysis of atmospheric pollution using this methodology, and of Alcántara (1995) who contributes very novel methods for the study of contamination from CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>x</sub>, some of which are considered in this paper.

### **Sources and initial assumptions**

A study using the input-output methodology begins by considering the interrelationships between the productive sectors and the environment. In our particular case, we are interested in studying these relationships in the Ebro Valley and in concentrating on water pollution. We do this by adding to the tables a number of additional rows that reflect the direct unitary returns and the direct unitary pollution for four polluting agents, BDO, TSS, Nitrates and

Phosphates. This procedure has been followed for the four economies of the Valley, that is to say, Lérida-Tarragona, Aragón, Navarre and Rioja, as well as for the aggregation of all these areas (the Ebro Valley). However, before considering these tables it is necessary to make a number of observations with respect to the sources and the initial assumptions made for the study.

The multisectorial descriptions have been obtained from the tables corresponding to each region. The study has been carried out for 12 representative sectors. The aggregation and sector selection criteria, as well as the original tables, can be seen in Sánchez-Chóliz (1997) and Sánchez-Chóliz and Duarte (1997).

For the unitary returns and pollution coefficients, we have used those published in the environmental input-output tables for Andalucía, and have adjusted them for the Ebro Valley by assuming weights that take into account both the weight of the different industrial activities in the economy and the additional data on returns in Aragón. Similarly, for the coefficient of the agricultural sector, account has been taken of the average crop distribution in the regions, considered at 1992, with this information being taken from the Agrarian Statistics Yearbook (MAPA, 1992). Starting from the primary coefficients and from the tables we have obtained the main returns and pollution indicators. The productive structures of Andalucía and of the Ebro Valley are, undoubtedly, very different, but there nevertheless seems to be a similar pattern of behaviour with respect to returns pollution. Although the consumption of water is determined to some extent by the characteristics of the geographical environment in which the industries operate (and it is for this reason that the consumption of water, and therefore the volume of returns, has been adjusted with the estimations for the Valley), the absence of different regulations between regions with respect to water pollution control policies causes us to think, *a priori*, in similar pollution behaviour.

Logically, the use of input-output models supposes that we first assume the linearity of the production function and the constancy of the technical coefficients (assumptions that have often been the subject of criticism). Additionally, we must assume the constancy of the returns and pollution coefficients and the lack of pollution on the part of the river itself. This supposes that we take as a starting point the self-purifying capacity of the river in the absence of productive activity and, therefore, we assume that each industry receives unpolluted water and that the pollution found downstream of its activity corresponds only to that industry.

### **3. The application of the input-output methodology to water pollution in the Ebro Valley**

The relationship between productive sectors can be expressed by way of the following equation:

$$X = AX + Y \quad (1)$$

where  $X$  is the productions vector,  $Y$  is the final demand vector and  $A$  is the technical coefficients matrix.

Let us define a matrix  $C$ , which a matrix of direct unitary pollutants where each element  $c_{kj}$  represents the unitary returns (for  $k=1$ ) and the direct unitary pollution of each type produced in sector  $j$ . The direct unitary returns are expressed in m3/million pesetas, whilst the pollutants are expressed in kg/million pesetas.

The coefficient, adjusted to 12 sectors, can be seen in Table 1.

If we pre-multiply expression (1) by vector  $C$ , we obtain:

$$E = CX = CAX + CY \quad (2)$$

where  $E$  is the matrix of total returns and pollutions of the economy.

Expression (1) can also be written as:

$$X = (I - A)^{-1}Y \quad (3)$$

where  $(I - A)^{-1}$  is the Leontief inverse matrix. The total by columns of the  $\alpha_{ij}$  elements of the inverse provide us, for each sector, with the direct and indirect input requirements when the final demand of each sector increases by one unit.

If we pre-multiply by  $C$ , we obtain:

$$VC = CX = C(I - A)^{-1}Y \quad (4)$$

We call the generic element of this matrix,  $VC_{kj}$ , the “valuation in k-type pollution”, where this represents the k-type pollution directly or indirectly generated by the sector  $j$  in obtaining its final demand. In the same way:

$$vc = C(I - A)^{-1} \quad \text{with } vc_{kj} = \sum_{i=1}^n c_{kj} \alpha_{ij} \quad (5)$$

is the matrix of “pollution values” associated with the backward linkages or unitary coefficients of backward linkages, and which shows the pollution directly and indirectly generated by the sectors in obtaining one unit of final demand. It measures the backward linkages in the sense that they are indicators of the capacity of the different sector to “drag” the others to produce resources, and therefore to pollute, with these resources being used as inputs to obtain one unit of final demand. The interpretation of these coefficients has to be made in terms of “values” (the Marx value of labour, or water value (Sánchez-Chóliz et al.,

1994). The interpretation of these coefficients as values opens an avenue for us to compare these with the monetary values of specific types of economic activities. Similarly, these coefficients are interpreted by Pasinetti as vertical integration coefficients.

We can also construct other indicators, paying attention to the role of the different sectors as suppliers of inputs for other productive sectors. In this case, the relevant matrix is not the technical coefficients matrix, but rather the  $B$  matrix of distribution coefficients. Although there is a relationship between both matrices, working with the technical coefficients and distribution matrices corresponds to demand-side and supply-side approaches to the model, respectively. For a more detailed study, see Pulido and Fontela (1993)<sup>1</sup>. These coefficients are called the forward linkage coefficients and measure the capacity of each sector to impel the production of other sectors, in the sense of the sales that this sector makes to the other sectors in the economy. Let us describe the unitary forward linkage in the pollution as:

$$ic_{ki} = c_{ki} \sum_{j=1}^n \alpha_{ij} \quad (6)$$

which is the returns or pollution generated by the  $i^{\text{th}}$  sector (of type  $k$ ) in the face of an increase of one unit in the demand of all the sectors. Pajuelo described it in terms of the forward linkage potential in the emission and it is a measure of the sensitivity of each sector to be forced by the economy to generate a specific type of pollutant (given that the other sectors demands its products as inputs).

In the particular case we are analysing here, we can see from the pollution values that there is similar behaviour in the different regions on the part of particular sectors. Thus, in the Table of aggregated results for the Valley as a whole, we can note how the agriculture, livestock, agri-food and paper sectors have a greater backward linkage capacity with respect to the volume of returns. With respect to BDO pollution, the backward linkage sectors are metals, motor vehicles and construction, given that one of the activities that produces most BDO pollutants is precisely metal transformation, whilst both construction and the motor vehicle industry are closely associated to this type of activity. Also note that important BDO value in the manufacturing sector: however, following this logic, the value is not distributed homogenously amongst the activities that make up this sector; rather, it is the industries with the greatest dependency on the metal sector that provide it with this value. With respect to TSS pollution, it is the energy, non-metal and paper sectors that display the greatest backward



linkage, with the other sectors displaying values that are similar amongst themselves but significantly lower than these first three sectors.

With respect to forward linkages, the highest values for the volume of returns are found in the agriculture, chemicals and paper sectors; for BDO, the highest values are found in the livestock, paper and metal sectors; for TSS, in energy, paper and non-metals; and for the other pollutants, in livestock and agriculture.

The results for the four individual regions and for their aggregation are set out in Table2.

On the basis of such indicators, Pajuelo adapts those constructed by Rasmussen in order to determine the key sectors and proposes the relative backward and forward linkage indicators in pollution. For the case of water pollution, and following Pajuelo's terminology, we have defined the following two coefficients:

$\mu_j$ : the relative backward linkage coefficient in pollution. This shows the importance that the returns and pollution of sector  $j$  have in the total pollution that can be assigned to the productive sector. It allows us to see the polluting role played by one sector, in that it incorporates the inputs of the other sectors (that pollute) in its productive process.

$$\mu_j = \frac{\frac{1}{n}vc_{kj}}{\frac{1}{n^2} \sum_{j=1}^n vc_{kj}} \quad (7)$$

In an analogous manner, we can construct the relative forward linkage coefficients ( $\mu_i$ ) that demonstrate the extent to which the total returns of one sector varies in the face of an increase in the final demand of all the sectors in relation to the average behaviour of the productive system.

$$\mu_i = \frac{\frac{1}{n}ic_{ki}}{\frac{1}{n^2} \sum_{i=1}^n ic_{ki}} \quad (8)$$

Both indicators, although operative, are easily open to criticism in that they are posed in relation to average behaviour, and where they are obtained by considering a simple average. To correct this problem, recourse is very often made (although not in this study) to Growth Equalised Coefficients (Pulido, 1993) which weigh the forward and backward linkages with the real sectorial structure of the final demand.

Rasmussen establishes the sector classification on this basis, whilst Pajuelo establishes the same classification by reference to the indicators adapted to atmospheric pollution.

	$\mu_j > 1$	$\mu_j < 1$
$\mu_i > 1$	key sectors	sector that exhibit forward linkage in the emission
$\mu_i < 1$	sectors that exhibit backward linkage in the emission	other sectors

The key sectors are identified as those with a marked polluting character as the demander of inputs and as the suppliers of resources to other sectors. In this sense, any pollution-reducing activity in these key sectors that might affect their production could have serious consequences for the whole productive system.

In our analysis we can observe a similar behaviour in all the regions. The coefficients data for the Valley are contained in Table 3. The different sectors are classified (by type of pollutant) as follows. With respect to the volume of returns, the key sectors are agriculture and paper, for backward linkage, they are livestock and agri-food and for forward linkage, the chemical sector. Note that Lérida-Tarragona and in La Rioja, the chemical sector does not appear to be important from the forward linkage point of view.

As regards BDO pollution, only the chemical sector appears to be key and only the motor vehicle sector exhibits backward linkage. These results are common for all the regions.

For TSS pollution, the key sectors are energy and non-metal, whilst in this case the paper sector exhibits backward linkage.

Finally, with respect to the other pollutants, the agriculture and agri-food sectors obtain the higher values of these indicators in all the regions. For Nitrates, agriculture and livestock are the key sectors, with an average coefficient that is significantly higher than the rest. The agri-food sector exhibits backward linkage with respect to Nitrate pollution. However, agriculture is not a key sector for Phosphate pollution and only livestock exhibits very significant backward and forward linkages. The agri-food sector continues to stand out in all regions as a backward linkage sector with respect to pollution.

As a result, we can see that in all cases there are three significant sectors, either as key sectors or as sectors that exert backward linkage over the others, thereby forcing water pollution, namely the agriculture, livestock and agri-food sectors. Also note the difference between sectors with respect to the different types of pollutants. The importance of the backward linkage in terms of BDO is concentrated fundamentally in the industrial sectors (chemicals,

paper, metal and motor vehicles), whilst the responsibility for Phosphate and Nitrate pollutants lies almost entirely with the agriculture and agri-food sectors.

Similarly, the paper sector stands out with respect to the volume of returns. This is quite logical, given that this sector receives inputs from the agricultural sector (a large-scale consumer and also with important volumes of returns), whilst it also supplies resources to almost all the sectors of the economy. The chemical industry also appears as an important sector from the point of view of water pollution, especially in Aragón and Navarre. Both in the different regions and in the Valley as a whole, there appear to be no clear forward linkages. The results for the four regions can be found in Sánchez-Chóliz and Duarte (1998). However, it must be said that the use of these indicators to determine key sectors has been heavily criticised, in that they do not provide information on their degree of dispersion; that is to say, on the extent to which the pollution generated by way of intersectorial relationships is concentrated in a reduced set of sectors or whether it depends on the operation of almost all the sectors of the economy.

#### **4. Trade-offs between pollution and economic variables**

In the search for better pollution indicators that might assist us in determining which are the key sectors of the economy with respect to any type of pollution, Karunaratne (1989) has proposed the trade-offs between energy and economic variables. The idea is that any measure for the reduction of pollution must take into account the repercussions in terms of income or employment in the economic sectors. The trade-offs approach and, on this basis, the extension of the concept of elasticity, allows us to examine these types of relationships more deeply.

The way to construct the trade-offs indicators between environmental and economic variables can be found in Alcántara (1995). On the basis of the pollution values (backward linkage coefficients in the pollution), the income values (represented by the added value coefficients), and the labour values, we can obtain the income value and labour value ratios per unit of each type of pollution value. The average ratios are calculated in a similar way and the sectors are ranked from the highest to the lowest value of these ratios, first according to the income criteria and thereafter according to the employment criteria. The results for the whole of the Ebro Valley are contained in Table 4, whilst the results for each of the four regions can be found in Sánchez-Chóliz and Duarte (1998).

In all cases, the agriculture, paper, livestock and agri-food sectors are found below the sectorial average, which means that the “cost”, in terms of added value and employment of

choosing these sectors for the reduction of pollution will have a lower impact on these variables than in the other sectors of the economy. We can also see that these sectors, with a low “opportunity cost” (Alcántara, 1995), are also the most important sectors with respect to direct and total pollution. In the case of BDO pollution, these sectors are joined by the paper and metal sectors. We can speak of these sectors as being key in terms of the triple objective of the control of pollution and the maximisation of income (or added value) and employment. It is also interesting to note the repercussion of the percentage reductions of demand on the total direct and indirect pollution generated by the sectors. In our approach to this question we can consider the pollution elasticities with respect to the sectorial demands. The construction of the elasticity vectors is carried out in the traditional way, considering the sectorial participation of demand over production. For a more complete study of this theme, see Pulido and Fontela (1993).

If we rank the pollution-demand elasticities from the highest to the lowest, and joining this ranking with the earlier ones, we have the sectors in which the impact on total pollution that results from a reduction in demand is as high or as low as the opportunity cost of reducing the pollution of a specific type by one unit (Alcántara, 1995).

In the application to the Ebro Valley, we can note that in this case there are differences between regions. As regards the volumes of returns, whilst in Lérida-Tarragona and Aragón the highest values are obtained for the construction and services sectors, in Navarre these values correspond to the agri-food sector, followed by services, motor vehicles, chemicals and agriculture, and in La Rioja, the agri-food sector stands out clearly from the rest.

When referring to BDO elasticity, in Lérida-Tarragona, the highest values correspond to the agri-food and construction sectors; in Navarre, the highest elasticity is found in the metal, livestock and agri-food sectors; finally, in La Rioja, the highest elasticities are also found in the livestock and metal sectors.

In all regions, Nitrate and Phosphate pollution exhibits the highest values in the agri-food sector, followed some way behind by agriculture and livestock.

In the light of the above, it is now possible to observe the behaviour of the different sectors with respect to the relationship between their economic and environmental variables. In general terms, it is the agriculture, livestock and agri-food sectors which directly and indirectly emit the highest volumes of returns and of Nitrate and Phosphates pollution and for which the “opportunity costs” are lower in terms of added value and employment. This situation extends to the paper sector (also in terms of volume of returns) and to the metal

sector for BDO pollution, However, the results are not so conclusive for TSS pollution. The other sectors are less significant, and their behaviour varies according to the region. In summary, it is necessary to examine more deeply the polluting behaviour of the three significant sectors (agriculture, livestock and agri-food), and we will do this using the subsystems technique.

## 5. Pollution-generating subsystems

This technique consists of breaking-down the vector of the  $k$  type pollutants generated directly and indirectly by one sector into its two components: that generated in obtaining its productive resources and that generated directly in obtaining its final demand.

On the basis of the  $C$  matrix of direct unitary returns and pollution coefficients, we can express the subsystem to any sector as:

$$CAX^{(i)} + CY^{(i)} = CX^{(i)} \quad (9)$$

The first addend expresses the pollution of the  $i^{\text{th}}$  sector in the process of obtaining its productive inputs, whilst the second correspond to the pollution that can be directly assigned to its final demand. The subsystems technique operates on the basis of the Pasinetti and Sraffa analysis. Its very complete application to the case of atmospheric pollution can be found in Alcántara (1995).

In this paper, and given that from the previous analysis we have determined the important role of the agriculture, livestock and agri-food sectors in the Ebro Valley, and in relation to the different types of pollution, we will adopt this technique to briefly examine the origin of the pollution in these sectors. For the theoretical implementation of the subsystems technique to the case of water pollution, and for the regional results obtained, see Sánchez-Chóliz and Duarte (1997,2). Table 5 presents the results for the three subsystems, using data for the whole of the Ebro Valley.

Note that for the agri-food sector, both with respect to returns and to the different types of pollutants, the impact of pollution in final demand is very limited, around 5%. That is to say, almost all the pollution that can be assigned to the agri-food sector comes from the inputs used in its productive processes and in its own inputs. However, the contrary is the case with the agriculture sector, where almost 90% of the returns impact on the products that are directly aimed at final demand, with the same thing occurring with Nitrate pollution in this sector, although to a lesser extent. In the livestock sector, the majority of Nitrate and Phosphate

pollution goes to products that constitute its final demand, whilst in terms of volumes of returns, the percentage of pollution in the final demand over the total is much lower, around 20%, and in BDO the responsibility is divided almost equally between intermediate inputs and final demand.

If we also analyse the sectorial origin of the pollutants (in Table 6 we present, by way of example, the analysis of the three subsystems by reference to the volume of returns), we can note that, with respect to the volumes of returns, this lies in the purchases of inputs made from the agricultural sector (around 80% and close to 60% for the sector itself). Concerning BDO, the pollution for all three subsystems comes from the purchases they make from the metal sector (around 80%, with this percentage being 90% for the agriculture sector). The origin of TSS pollution comes from the purchases made from the energy sector (with purchases from the non-metal sector occupying second place). Nitrate and Phosphate pollution is almost entirely due to inputs coming from the livestock sector. Therefore, it can be said that the pollution suffered by these sectors, which itself represents a large percentage of the total pollution of the system, has its origin, on the one hand, in the primary sectors (agriculture and livestock) and, on the other, in the sectors most directly related with them and which are, at the same time, the main suppliers of inputs (energy and machinery). Thus, we can see how the pollution that can be assigned to these three subsystems does not stop with them, but rather has a direct dependency on the production methods. A measure for the reduction of pollution that is implemented in the machinery manufacturing process or in the sources of energy supply will have a direct repercussion on the pollution that can be directly or indirectly assigned to the agriculture or agri-food sectors and, in turn, by way of the inputs that these sectors sell to the other sectors of the economy, on the polluting activity of the economy as a whole.

## **6. Conclusions**

In this work, we have applied some of the tools made available by the input-output methodology to the study of water pollution in the Ebro Valley. We have offered no more than a limited analysis, which only purports to demonstrate some of the possibilities that can be found in the study of the relationships between the economy and the environment. Notwithstanding this qualification, this initial analysis allows us to draw the following conclusions:

First, the role played by the agriculture, livestock and agri-food sectors, both as direct and indirect polluters, is quite clear, especially with respect to the volume of returns and to Nitrate

and Phosphate pollution. It is fundamental that we note the important backward linkage exhibited by the agri-food industry (one that is key in some regions). Emphasis should also be placed on the different roles played by the sectors according to the type of pollution being considered, in that sectors such as metal or paper are important in BDO pollution and volumes of returns, but not significant with regards to Nitrates and Phosphates.

Secondly, and although this has not been undertaken in our paper, it would be interesting to examine more deeply the relationships that exist in terms of BDO pollution. Here, we should recall the concern of many authors to extend the input-output tables in order to introduce the anti-polluting sector. On the basis of analyses similar to the type presented in this paper, we would be in a position to extend these tables in such a way that, by establishing the direct and indirect “responsibilities” of the sectors, we could relate these with the equivalent inhabitant measure. In this sense, article 2 of EU Directive 91/271/EEC of 21<sup>st</sup> May 1991 establishes that an equal inhabitant corresponds to pollution in terms of BDO5 of 60gr/day. Using this as a basis, and according to the characteristics of the returns and the purifying conditions, we could determine the purification cost ratios, which would be a way of relating, at least to a certain extent, the purification costs with the returns directly and indirectly generated by the industries. A whole new line of research would thereby be opened, in which we could look for new pollution indicators and for an extension of the traditional input-output tables in which the environmental sector could be reflected in a more coherent manner.

### **Footnotes:**

<sup>1</sup> In our case, and for purely operative reasons, we consider the equilibrium of supply with demand, an aspect that does not generally hold and which leads to changes in the effects of up to 20%. This allows us to define the distribution coefficients matrix  $B$  as the transposition of the coefficients matrix. For a more detailed study of this theme, see Sánchez-Chóliz and Duarte (1997), in an application to the irrigated areas of the Ebro Valley.

### **References**

Alcántara, V. (1995): Economía y contaminación atmosférica: hacia un nuevo enfoque desde el análisis input-output. Doctoral Thesis. Barcelona . Unpublished.

Leontief, W. and Ford, D. (1972): Air pollution and the economic structure: empirical results of input-output computations, in Input-Output Techniques, by Brody and Carter (eds.). North Holland Publishing Company, Amsterdam.

Pajuelo, A. (1980): Equilibrio general versus análisis parcial en el análisis input-output económico ambiental: Una aplicación al análisis de la contaminación atmosférica en España, Revista del Instituto de Estudios Económicos nº3. Madrid.

Pasinetti, L. (1977): Aportaciones a la teoría de la producción conjunta. FCE. México (1986).

Pulido,A. and Fontela,E. (1993): Análisis input-output. Modelos, datos y aplicaciones. Pirámide. Madrid.

Rasmussen, P. (1956): Relaciones intersectoriales. Ed.Aguilar . Madrid.

Sánchez-Chóliz, J. Arrojo, P. and Bielsa, J. (1994): Valores agua para Aragón, paper presented at the IV Jornadas de Economía Crítica. Valencia.

Sánchez-Chóliz, J. (1997): Efectos económicos y sociales de las inversiones en riego contempladas en la propuesta del Plan Hidrológico de la Cuenca del Ebro. Confederación Hidrográfica del Ebro. Zaragoza.

Sánchez-Chóliz, J. And Duarte, R. (1997): Efectos económicos del Plan Hidrológico de la Cuenca del Ebro. Análisis a través del incremento de valor añadido. Working paper. Department of Economic Analysis. University of Zaragoza.

Sánchez-Chóliz, J. And Duarte, R. (1998): Impacto de la estructura productiva en la calidad del agua. Aplicación al Valle del Ebro. Working paper. Department of Economic Analysis. University of Zaragoza.

Subdirección General de Estadística y Análisis Sectorial (1995): Anuario de Estadística Agraria, 1993. Ministerio de Agricultura, Pesca y Alimentación. Madrid.



Table 1

<i>Direct unitary coefficients</i>					
	<i>return*</i>	<i>BDO**</i>	<i>TSS**</i>	<i>Nitrates**</i>	<i>Phosphates**</i>
<i>Agriculture</i>	1218.8	0.0	0.0	67.4	0.6
<i>Livestock</i>	87.0	1396.9	0.0	605.8	347.2
<i>Energy</i>	29.9	0.1	2087.6	0.0	0.0
<i>Metal</i>	48.5	13000	126.8	0.0	0.0
<i>Non-metallic</i>	28.7	10.0	1573.2	0.0	0.0
<i>Chemicals</i>	152.0	79.9	105.1	0.0	0.0
<i>Motor-vehic.</i>	9.4	290.6	72.6	0.0	0.0
<i>Agro-food</i>	16.6	55.1	14.4	0.0	0.0
<i>Manufactures</i>	12.4	55.6	43.6	0.0	0.0
<i>Paper</i>	262.9	428.0	261.3	0.0	0.0
<i>Construction</i>	11.4	0.0	0.0	0.0	0.0
<i>Services</i>	32.7	3.1	4.7	0.9	0.0

\*in m3/million pesetas

\*\*in kg/million pesetas

Table 2

<i>Backward linkages</i>					
	<i>return*</i>	<i>BDO**</i>	<i>TSS**</i>	<i>Nitrates**</i>	<i>Phosphates**</i>
<i>Agriculture</i>	1360.6	1828.0	331.6	130	33.6
<i>Livestock</i>	497.8	2817.3	263.9	718.8	400.8
<i>Energy</i>	63.0	1092.3	3076.7	2.0	1.1
<i>Metal</i>	123.8	21413.5	478.2	5.5	2.8
<i>Non-metallic</i>	78.8	1761.1	2280.4	4.6	2.3
<i>Chemicals</i>	290.4	1662.9	668.4	12.6	6.4
<i>Motor-vehic.</i>	85.1	6300.6	382.8	8.0	4.1
<i>Agro-food</i>	545.9	1826.3	321.8	193.8	96.7
<i>Manufactures</i>	112.4	1662.6	321.3	36.4	19.6
<i>Paper</i>	454.4	1869.4	810.1	27.5	14.6
<i>Construction</i>	61.9	3464.9	526.9	4.7	2.4
<i>Services</i>	6.9	712.1	196.3	12.1	5.7
<i>Forward linkages</i>					
	<i>return*</i>	<i>BDO**</i>	<i>TSS**</i>	<i>Nitrates**</i>	<i>Phosphates**</i>
<i>Agriculture</i>	2275.3	0.0	0.0	125.8	1.1
<i>Livestock</i>	147.5	2367.6	0.0	1026.7	588.4
<i>Energy</i>	83.3	0.2	5810.5	0.0	0.0
<i>Metal</i>	158.4	42411.3	413.6	0.0	0.0
<i>Non-metallic</i>	45.1	15.8	2467.2	0.0	0.0
<i>Chemicals</i>	366.6	192.8	253.5	0.0	0.0
<i>Motor-vehic.</i>	13.3	414.3	103.6	0.0	0.0
<i>Agro-food</i>	33.4	110.8	28.9	0.0	0.0
<i>Manufactures</i>	27.7	123.7	96.9	0.0	0.0
<i>Paper</i>	468.5	762.5	465.6	0.0	0.0
<i>Construction</i>	13.6	0.0	0.0	0.0	0.0
<i>Services</i>	128.6	12.3	18.4	3.5	0.7

\*in m3/million pesetas

\*\*in kg/million pesetas

Table 3

<i>Relative backward linkages(<math>\mu_i</math>)</i>
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	<i>return*</i>	<i>BDO**</i>	<i>TSS**</i>	<i>Nitrates**</i>	<i>Phosphates**</i>
<i>Agriculture</i>	4.34	0.47	0.41	1.35	0.68
<i>Livestock</i>	1.58	0.73	0.33	7.46	8.15
<i>Energy</i>	0.20	0.28	3.82	0.02	0.02
<i>Metal</i>	0.39	5.54	0.59	0.06	0.06
<i>Non-metallic</i>	0.25	0.45	2.83	0.05	0.05
<i>Chemicals</i>	0.92	0.43	0.83	0.13	0.13
<i>Motor-vehic.</i>	0.27	1.63	0.47	0.08	0.08
<i>Agro-food</i>	1.74	0.47	0.39	2.01	1.97
<i>Manufactures</i>	0.36	0.43	0.39	0.38	0.39
<i>Paper</i>	1.45	0.48	1.01	0.28	0.30
<i>Construction</i>	0.19	0.89	0.65	0.05	0.05
<i>Services</i>	0.28	0.18	0.24	0.12	0.12
<b>Relative forward linkages (<math>\mu_i</math>)</b>					
	<i>return*</i>	<i>BDO**</i>	<i>TSS**</i>	<i>Nitrates**</i>	<i>Phosphates**</i>
<i>Agriculture</i>	7.26	0.00	0.00	1.30	0.02
<i>Livestock</i>	0.47	0.61	0.00	10.66	11.96
<i>Energy</i>	0.27	0.00	7.22	0.00	0.00
<i>Metal</i>	0.50	10.96	0.51	0.00	0.00
<i>Non-metallic</i>	0.14	0.00	3.06	0.00	0.00
<i>Chemicals</i>	1.17	0.05	0.31	0.00	0.00
<i>Motor-vehic.</i>	0.04	0.11	0.13	0.00	0.00
<i>Agro-food</i>	0.11	0.03	0.04	0.00	0.00
<i>Manufactures</i>	0.09	0.03	0.12	0.00	0.00
<i>Paper</i>	1.49	0.20	0.58	0.00	0.00
<i>Construction</i>	0.04	0.00	0.00	0.00	0.00
<i>Services</i>	0.41	0.01	0.02	0.04	0.01

Table 4

<b>Trade-offs in the Ebro Valley</b>													
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>mean</i>
<i>AV/vc<sub>1</sub></i>	0.0157	0.0153	0.0117	0.0113	0.0112	0.0085	0.0080	0.0031	0.0021	0.0019	0.0017	0.0007	0.0076
<i>WV/vc<sub>1</sub>*</i>	5.19	1.91	3.55	2.70	2.83	3.51	2.05	0.85	0.59	0.73	0.57	0.21	2.06
<i>AV/vc<sub>2</sub>**</i>	14.3	8.80	5.70	5.50	5.20	5.26	5.21	5.09	3.51	2.82	1.51	0.46	5.31
<i>WV/vc<sub>2</sub>***</i>	4.33	1.10	2.38	1.50	1.62	1.71	1.43	1.20	1.29	0.92	0.38	0.11	1.50
<i>AV/vc<sub>3</sub></i>	0.0052	0.0037	0.0029	0.0029	0.0029	0.0024	0.0020	0.0018	0.0013	0.0012	0.0003	0.0003	0.0022
<i>WV/vc<sub>3</sub>*</i>	1.57	0.37	1.23	0.97	0.89	0.62	0.53	0.6	0.37	0.33	0.09	0.03	0.72
<i>AV/vc<sub>4</sub></i>	0.48	0.21	0.20	0.18	0.12	0.08	0.07	0.03	0.03	0.01	0.00	0.00	0.12
<i>WV/vc<sub>4</sub>*</i>	59.53	68.72	46.67	45.99	30.09	25.56	19.73	9.78	10.87	2.28	1.61	0.50	26.78
<i>AV/vc<sub>5</sub></i>	0.95	0.41	0.39	0.35	0.23	0.18	0.14	0.07	0.05	0.03	0.01	0.00	0.23
<i>WV/vc<sub>5</sub>*</i>	119.17	135.36	91.94	90.60	58.36	54.17	39.11	18.37	20.13	8.81	3.22	0.90	53.35

\* in  $10^{-6}$  \*\* in  $10^{-4}$  \*\*\* in  $10^{-7}$

$c_1$ : water return,  $c_2$ :BDO,  $c_3$ :TSS,  $c_4$ :Nitrates,  $c_5$ :Phosphates

sectors: Agriculture(1), Livestock(2), Energy (3), Metal(4), Non-metallic(5), Chemicals(6), Motor-vehicles(7), Agro-food(8), Manufactures(9), Paper and printing(10), Construction(11), Services (12).

Table 5

<b>Pollution-generating subsystems in the Ebro Valley (in thousands of Tm)</b>			
	<i>Agro-food</i>	<i>Agriculture</i>	<i>Livestock</i>
<i>water return</i>	402.6	25.0	68.4

<i>BDO</i>	1347.2	322.7	23.6
<i>TSS</i>	234.8	58.5	43.9
<i>Nitrates</i>	147.4	11.0	18.8
<i>Phosphates</i>	73.6	5.8	8.9
<b><i>CY Agro</i></b>	<i>Agro-food</i>	<i>Agriculture</i>	<i>Livestock</i>
<i>water return</i>	12.6	215.2	14.4
<i>BDO</i>	41.9	0.0	232.5
<i>TSS</i>	10.9	0.0	0.0
<i>Nitrates</i>	0.0	11.9	100.8
<i>Phosphates</i>	0.0	0.1	57.8
<b><i>% final in total</i></b>	<i>Agro-food</i>	<i>Agriculture</i>	<i>Livestock</i>
<i>water return</i>	3.04	89.58	17.48
<i>BDO</i>	3.02	0.00	49.59
<i>TSS</i>	4.48	0.00	0.00
<i>Nitrates</i>	0.00	51.83	84.28
<i>Phosphates</i>	0.00	1.76	86.62

Table 6

<i>Origin of water return (in %)</i>			
	<i>Agro-food</i>	<i>Agriculture</i>	<i>Livestock</i>
<i>Agriculture</i>	86.18	63.07	86.20
<i>Livestock</i>	4.57	5.83	3.26
<i>Energy</i>	0.63	2.77	0.72
<i>Metal</i>	0.94	4.40	1.05
<i>Non-metallic</i>	0.11	0.23	0.09
<i>Chemicals</i>	2.61	15.94	3.38
<i>Motor-vehicles</i>	0.00	0.01	0.01
<i>Agro-food</i>	0.90	0.56	1.81
<i>Manufactures</i>	0.15	0.42	0.15
<i>Paper and printing</i>	2.23	2.94	1.50
<i>Construction</i>	0.03	0.12	0.05
<i>Services</i>	1.62	3.70	1.78