

**ENVIRONMENTAL IMPACTS OF A REGIONAL ECONOMY:
AN APPLICATION TO THE ARAGONESE ECONOMY (SPAIN)**

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Abstract:

The objective of this paper is to analyse the environmental impacts of a regional economy (Aragon, Spain) by way of its atmospheric emissions. Our starting point is the construction of a Social Accounting Matrix with Environmental Accounts for this region. We calculated environmental indicators from the underlying SAM model considering the households and foreign sector accounts as exogenous accounts, while government, labour, capital and other accounts were treated as endogenous. The impacts obtained and their per capita distributions are the bases of our approximation to the environmental impacts. The pollution measures are estimated for seven categories of pollution (CO₂, CH₄, N₂O, HFC, PFC, SF₆ y CO₂ eq). The analysis reveals that pollution in Aragon is closely linked to food production, energy and transportation material. 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 Aragonese economy avoids a great deal of pollution by importing inputs, which pollute where they are produced.

Keywords: CO₂ emissions, Social Accounting Matrix, regional economy.

JEL classification: C67, D57, Q00, Q51, Q53, R10, R15.

1. Introduction

Since Wackernagel and Rees 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), abundant literature has emerged to develop calculation techniques applied to analyse the environmental impact in specific populations (see Bicknell et al., 1998; Loh, 2000; and Ferng 2001 and 2002). Agenda 21 (UN, 1993) also states, in the part dedicated to local agendas the need of computing for the environmental impact at the local levels.

Despite of the specificities in the computation of the Ecological Footprint and the controversial aspects of the measurement (see Ayres (2000), Herendeen (1998) for a review of these aspects), the concept of Ecological Footprint has opened the way in the search to provide methodologies, in words of Bicknell et al. (1998) the ‘snapshot’ of the resources required to support consumption given available technology and processes.

In some way, as Turner et al. (2007) recognize, “the focus of the Ecological Footprint is to capture the total (direct plus indirect) resource use embodied in final consumption in an economy”. In this context, input-output analysis, apart from showing the direct and indirect relationship between the economic sectors, has been revealed too

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as a suitable instrument to capture the total impacts (direct plus indirect) on environment as consequence of productive and consumption activity. The works of Bicknell et al. (1998), Ferng (2001, 2002) or Sánchez-Chóliz et al. (2007) are examples of how to use the input-output analysis to evaluate the impact on the natural resources associated with economic functioning. Moreover, Turner et al. (2007) provided a significant review of recent works regarding the relationship between production, consumption and environmental impacts using the input-output methodology in a national and international context.

However, few papers appear in this literature dealing with the environmental impacts of production and consumption paths in a regional context, Bussolo et al. (2002), Sánchez Chóliz and Duarte (2003), Manresa and Sancho (2004) or Velázquez (2006) being some of the exceptions. This lack of studies is mainly due to the absence of input-output tables and, specially environmental sectorially classified data at the regional or local level. Nevertheless, the regional perspective has, in our opinion, an special interest at least for two reasons: First, because the measures in the fighting against environmental degradation are mainly introduced and monitored at the regional level (the local-focus of the European Water Framework or the development of Regional Agencies for Climate Change Strategies are good examples of this regional interest), and secondly because the regional economic behaviour can be so different to the national average that the diagnosis obtained at the national level cannot be representative of significant local environmental pressures, which can produce biases in the policy making decisions.

In this context, our objective is to assess the environmental impact associated to the economic activity of a Spanish region, Aragón. More specifically, we will focus on the air pollution attributable to the production of goods in the region, for domestic consumption and exports taking account the six greenhouse gases considered by Kioto Protocol (CO_2 , CH_4 , N_2O , HFC, PFC, SF_6). The aragonese region is located in the North-East of Spain, close to the Pyrenees and in the main roads to Barcelona and Madrid, the two most populated cities in Spain. The main city in the region, Zaragoza and its surroundings concentrate most of the industrial sector in the region, with a more rural character for the rest of the territory. Aragon represents around 2.7% of the Spanish population and 3% of the Spanish GDP. The economic composition of Aragon is more oriented towards the agrarian sectors and also energy sectors than the Spanish average (the average sectoral participation in Aragonese GDP during the period 1995-2007 was Agriculture 5.99%, Energy 3.42%, Industry 21.79%, Construction 8.97% and Services 59.83%; the share of these sectors in Spain was Agriculture 3.96%, Energy 2.98, Industry 16.85%, Construction 9.36% and Services 66.85%). Moreover, during this period, Aragon represented around 3.7% of the Spanish Energy sector and around 5% of the Agrarian Spanish sector. This significant orientation towards the agrarian and the energy sector justifies, to some extent, the relatively high level of air emissions in Aragon. According to the most recent data (2007) provided by the CORINAIR inventory, the emissions of the aragonese economy were 23,303 kt, representing a 5.27% of the Spanish emissions (442,322 kt) and having increased by 30.7% since 1990.

Consumption patterns involve the demand of goods and services that can be either produced locally or imported (from the other regions in Spain or from abroad). The required production implies a direct and indirect use of resources in the different steps of the production process that could be captured in an input-output framework. However,

given that final demand is closely linked to available income, in which other institutional activities play a significant role (through labour and capital payments, taxes, transferences, and so on) the Leontief model has been expanded to include other activities not directly related with production. Therefore, we work within the Social Accounting Matrix (SAM) framework.

The results suggest that atmospheric pollution in the Aragonese territory is characterized by the following coordinates: pollutant-oriented rather than difusal, sectorially concentrated by pollutants and connection between environmental effects and household and foreign expenditure behaviors. The results also reveal the role played by institutions in the economic and polluting map.

The rest of the paper is structured as follows. Section 2 presents the methodology to calculate the embodied pollution within a SAM model. Section 3 is devoted to the steps followed in the construction of the dataset, that is to say, the SAM with environmental accounts in our regional context. In section 4 we describe the main results, and Section 5 closes the paper with a review of the main conclusions.

2. Methodology

Our framework is the Social Accounting Matrix expanded with Environmental Accounts, (SAMEA), for a regional economy. Given that the SAM offers a description of the relationship between productive and institutional agents in the economy (productive activities, productive factors, households, societies, public sector and foreign sector) is a suitable instrument for the study of the economic functioning in an area. Moreover, the relationship between the economic behaviour (trade policy, consumption patterns, and others) and the environment is clearly captured in the SAMEA context. As we will see, on the basis of the underlying SAM model, it is possible to evaluate the environmental impact associated with the different economic activities within the region.

More concretely, the typical structure of a SAM can be summarized as it is shown in Table 1. As can be seen, the SAM has a common core with the Input-Output table with additional disaggregated structures of income and expenditure.

Table 1. Structure of the SAM for Aragon

	1	2	3	4	5	6	7	Total income
1. Productive activities	X_{11}	0	X_{13}	0	X_{15}	X_{16}	X_{17}	X_{1j}
2. Productive factors	X_{21}	0	0	0	0	0	0	X_{2j}
3. Households	0	X_{32}	X_{33}	X_{34}	X_{35}	0	X_{37}	X_{3j}
4. Societies	0	X_{42}	X_{43}	X_{44}	X_{45}	0	X_{47}	X_{4j}
5. Public Sector	X_{51}	X_{52}	X_{53}	X_{54}	0	X_{56}	X_{57}	X_{5j}
6. Saving-Investment	0	0	X_{63}	X_{64}	X_{65}	0	0	X_{6j}
7. Foreign sector	X_{71}	0	X_{73}	X_{74}	X_{75}	X_{76}	0	X_{7j}
Total expenditures	X_{i1}	X_{i2}	X_{i3}	X_{i4}	X_{i5}	X_{i6}	X_{i7}	

As can be seen, a schematic SAM consists of seven groups of accounts, representing the different economic agents. In this representation, each X_{ij} is a matrix

showing the payments made by the “j” accounts to the “i” accounts. The inclusion of environmental accounts allows us to obtain a SAMEA structure (see Table 2).

Table 2. Structure of the SAMEA (with atmospheric emissions for Aragon)

	1	2	3	4	5	6	7	Atmospheric emissions
1. Productive activities	SAM							Atmospheric emissions accounts
2. Productive factors								
3. Households								
4. Societies								
5. Public Sector								
6. Saving-Investment								
7. Foreign sector								

In our case, given that we want to focus on the atmospheric pollution embodied in economic activities, we have included as Environmental Accounts those regarding atmospheric pollution. More concretely, six columns regarding the greenhouse gases considered in the Kyoto Protocol have been included (CO₂, CH₄, N₂O, HFCs, PFCs and SF₆). Additionally, the emissions of these gases have been converted to CO₂ equivalent units, in this way, the total emissions have been compiled in a seventh column. Each element of these columns shows the direct emission corresponding to the different economic agents.

In order to develop the model underlying to the SAM structure, the selection of endogenous and exogenous accounts can be shaped. In our case, given that our objective is to measure the total (direct plus indirect) pollution associated with the activity of households and foreign sector, only these accounts have been considered as exogenous. With this assumption, we are considering that all the other sectors in the economy operate to satisfy the final demand of households and foreign sector: in other words, all the economic and institutional activities interact in order to obtain the goods and services demanded by households and foreign sector.

Thus, if $\mathbf{y}$ represents the household and foreign sector income, and $\mathbf{x}$ is the vector of total income flows in the economy, the equilibrium equation can be expressed as follows:

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 & A_{14} & A_{15} \\ A_{21} & 0 & 0 & 0 & 0 \\ 0 & A_{32} & A_{33} & A_{34} & 0 \\ A_{41} & A_{42} & A_{43} & 0 & A_{45} \\ A_{51} & 0 & A_{53} & A_{54} & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \end{bmatrix} \Leftrightarrow \mathbf{x} = \mathbf{Ax} + \mathbf{y}$$

where $\mathbf{A}$ is the matrix of average expenditure propensities. Solving this equation for $\mathbf{x}$, the income for the endogenous accounts can be obtained as a function of $\mathbf{y}$.

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

where $\mathbf{M}=(m_{ij})$ is the matrix of Generalized Multipliers (equivalent to the Leontief inverse in the input-output framework). The generic element of this matrix (m_{ij}) shows the impact on the endogenous account i of an exogenous unitary shock of income in the j -account.

On the basis of this economic model, we can obtain the atmospheric emissions embodied in the households and foreign sector expenditures. To do this, let us consider $\mathbf{c}_k=(c_{ik})=(C_{ik}/x_i)$ the vector of direct pollution intensity for the pollutant k , whose elements compute the direct pollution per unit of production of the different goods and services (for the productive sectors) and the unitary pollution per unit of expenditure for the institutional accounts.

The direct and indirect economic relationships can be evaluated in terms of the embodied pollution. Thus, if we denote by $\hat{\mathbf{c}}_k$ the diagonal matrix formed by the elements of vector $\mathbf{c}_k$, and by $\mathbf{e}$ a unitary vector of the appropriate dimension, the vector of pollution values for pollutant k (λ_k) can be obtained

$$\lambda_k' = \mathbf{e}' \hat{\mathbf{c}}_k \mathbf{M}$$

The generic element, λ_{jk} shows the quantity of the k pollutant, emitted directly and indirectly by the economy in the process of generation of required inputs to satisfy one unit of exogenous household and foreign sector expenditure in the j -account. In other words, the pollution increases in the economy when the household and foreign sector expenditure in the endogenous j -account raises one unit. By construction, this vector is a valuation of the backward linkage of the different accounts in terms of pollution of the k -type.

Similarly, we can obtain the vector $\boldsymbol{\mu}_k = \hat{\mathbf{c}}_k \mathbf{M} \mathbf{e}$ whose generic element μ_{ik} shows the increase in the pollution generated by the account i as consequence of a unitary increase in the household and foreign sector expenditure in all the endogenous economic accounts. This index can be considered as a valuation, in terms of pollution, of the additional output required from account i to supply inputs required to fulfil the increased exogenous demand, that is, a valuation of the forward linkage¹.

In spite of the simplicity of these measures for explaining the origin and distribution of pollution (mainly related with the absence of weighting and the use of a quantity model to compute distributional impacts instead of a price model in the computation of $\boldsymbol{\mu}_k$) the information provided by these indexes can be useful for taking a first snapshot of the potential pollution linked to the household and foreign sector expenditure.

With the aim of synthesizing this information, and more significantly, of comparing the potential behaviour of an economic structure for different pollutants, the following methodology can be used, inspired in the *Multiplier Product Matrix* (MPM) and the associated landscape proposed by Sonis and Hewings (1999).

The idea of the MPM is to capture the effect of both backward and forward linkages providing the relationship between an account and all the other accounts or activities in the economy.

¹ Another approach to calculate the forward linkage is to use the supply-side or price input-output model.

Let us denote by T_k the sum of elements in matrix $(\hat{\mathbf{c}}_k \mathbf{M})$, $T_k = \sum_{i=1}^n \sum_{j=1}^n c_{ik} \mathbf{M}_{ij}$, the MPM for pollutant k is:

$$\mathbf{MPM}_k = \frac{1}{T_k} \mathbf{\mu}'_k \boldsymbol{\lambda}_k = \frac{1}{T_k} (\mu_{1k} \quad \dots \quad \mu_{nk}) \begin{pmatrix} \lambda_{1k} \\ \vdots \\ \lambda_{nk} \end{pmatrix}$$

Given that this matrix captures the relationship between all the economic activities in terms of pollution, its rows and columns can be organized following a rank-size hierarchy. The transformed matrix coefficients can be illustrated graphically in order to show the “pollution landscape of the region”. Comparison of these landscapes for the different pollutants considered gives us some first insights on the sectors more sensitive to generate pollution when household and foreign expenditure changes.

However, a significant deficiency of all these unitary indicators is that they offer information on the impact intensity (for example when the household and foreign consumption increases in one unit) rather than on the real global pollution impact associated with the household and foreign expenditure of the economy. Bearing in mind that a sector can be highly pollutant per unit of expenditure in its produced goods, the environmental impact associated with the activity of this sector could not result significant if these goods represent a small fraction of the total expenditure. In order to capture this “scale effect”, we can weight the pollution values by the household and foreign expenditure vector. Thus, we obtain the embodied pollution in the household and foreign expenditure in the different accounts, represented by vector $\boldsymbol{\Lambda}_k = \mathbf{e}' \hat{\mathbf{c}}_k \mathbf{M} \hat{\mathbf{x}}$. Similarly, the forward coefficients can be weighted by their corresponding exogenous final demand, $\boldsymbol{\Gamma}_k = \hat{\mathbf{c}}_k \mathbf{M} \mathbf{x}$. Obviously, both approaches have to be coincident so, the economy has to satisfy that $\boldsymbol{\Lambda}_k \mathbf{e} = \mathbf{e}' \boldsymbol{\Gamma}_k = C_k$ with C_k being the total direct pollution in the economy linked with the foreign and household activity. Finally, these indicators will be related to the population in the region to give some idea about the per capita environmental pressures in the territory.

3. Data

A first step for the analysis is to elaborate the Social Accounting Matrix with Environmental Accounts (SAMEA) for the region studied, Aragón. To do this, we have to deal with two types of information (economic and environmental information).

With respect to the economic information, a SAM has been constructed on the basis of the Input-Output Framework for Aragon (Ibercaja, 2003). Other statistical sources used are Household budget survey (INE, 2002a), Regional Accounts (INE, 2002b), and National Accounts (INE, 2005). The Aragonese SAM has been elaborated with 37 accounts: 28 productive accounts and 9 institutional accounts (two for productive factors, one for households, societies, public sector and saving-investment, and three for foreign sector). On the process and economic results derived from the SAM regional analysis for Aragon see Flores and Mainar (2009).

With respect to the environmental information, the NAMEA methodology is followed to construct a environmental dataset compatible with the economic accounts. As it has been said, the *Atmospheric Pollution Accounts* include the most relevant greenhouse gases considered in the Kyoto Protocol, Carbon Dioxide, CO₂, Nitrous Oxide, N₂O, Methane, CH₄, Hydrofluorcarbrides, HFC, Perfluorocarbide, PFC, Sulfur Hexafluoruro, SF₆, and an account that summarizes all these emissions measured in equivalent unities of CO₂, according to the warming potential of IPCC 1995 (MMA, 2009).

To elaborate the Aragonese *Atmospheric Pollution Accounts* we have used the methodology that is followed by the Spanish Nacional Institute in order to obtain the Spanish Environmental Acccounts. The regionalization of the environmental impacts requires using the regional CORINAIR Inventory. The CORINAIR (Coordinated System and information on the Situation of Natural Resources and Environment), promoted by the European Union since 1986, considers the potentially pollutant activities classified according the SNAP criteria (Selected Nomenclature for Air Pollution).

In order to do compatible both kinds of information (economic information, based on an economic account criteria; and environmental information, based on the CORINAIR criteria), some adjustments have to be made. First, the emissions with the CORINAIR methodology are classified by combustion processes (SNAP-97 Nomenclature) while that with the NAMEA methodology the emissions are classified by productive activities (NACE Nomenclature). Secondly, with NAMEA the analysis unity is economic activity unity resident in national territory, while that with CORINAIR methodology the analysis unities are the emissions produced in the national territory by resident or no resident activity units. Third, the NAMEA methodology registers only the emissions produced by economic agents, while the CORINAIR methodology registers the emissions generated by the nature too.

Tudini and Vetrella (2004) and the ISTAT (Istituto Nazionale di Statistica), in the construction of the NAMEA for Italy, deal with these problems and suggest some steps to make compatible the information. This methodology was followed in our work².

One final comment has to be devoted to the pollution associated with Aragonese imports of goods and services. Given that no information about pollution can be directly obtained, this pollution has been computed by assuming the hypothesis of common technology for Spain and for foreign countries. Under this hypothesis, all the products imported have been generated outside with a technology similar to the Spanish one. More concretely, we calculate the pollution values using the unitary pollution coefficients and multiplying these coefficients by the Leontief inverse obtained from the Spanish SAM (Spanish pollution value). The estimation of GHG pollution associated with imports will be obtained by multiplying these values by the vector of imports. Thus, we are assuming that imports come to the Aragonese region as a final product generated outside with the same technology that operates in Spain. This hypothesis is supposed taking account that the 62% of total imports come from the Rest of Spain.

² For details on this process of building data for Aragon, see Flores (2008).

4. Results

4.1. Unitary pollution and Environmental landscapes

A first insight of the pollution behaviour of the Aragonese economy can be obtained by way of the unitary forward and backward linkages and the associated pollution landscape. As an example, this representation has been built for three main pollutants (CO_2 , CH_4 and N_2O) and for equivalent CO_2 emissions.

The idea underlying the landscape pictures is to represent the intensity and distribution of the intersectorial relationships, evaluated, in our case, in terms of the pollution embodied in these transactions. Therefore, an economy without significant interindustry linkages from the point of view of pollution will be reflected in a low and flat landscape.

A first feature is that, as can be seen in the figures 1, 2, 3 y 4, in the Annex, for the different pollutants considered, unitary pollution is concentrated in very few economic accounts, showing a highly concentrated and asymmetric landscape. Mainly, these economic accounts are Energy products (AP3), Agriculture (AP1), Livestock (AP2) and Chemicals (AP7).

A second relevant feature is that main unitary polluters are different depending on the pollutant considered. More concretely, if we look at the CO_2 emissions, Energy products (AP3), Mining and non metallic products (AP6), Transportation and communication (AP19) and Water (AP4) have the highest unitary backward linkage. Also Energy products (AP3), Mining and non metallic products (AP6) and Transport and communication (AP19), together with Agriculture (AP1), are at the top of the classification when we consider the unitary forward linkage. This shows us that these activities pollute for other activities and institutions. Although these accounts pollute very much to produce their goods and services, those goods and services are used as input by the different productive activities in the economy. Similarly, the accounts Livestock, Food, beverage and tobacco, Energy products, and Other sale services are the most relevant on the direct and indirect unitary pollution in terms of CH_4 . However, when N_2O pollution is considered the leading sector is Agriculture, followed by Food, beverage and tobacco, Livestock, Wood and Cork (except wood furniture). The pollution expressed in terms of equivalent CO_2 shows that Energy and Extractives activities (energy products, mining and non metallic products), and the agro food industry (comprising Agriculture, Livestock and Food industry) are the sectors with highest unitary impact per unit of household and foreign expenditure. On the contrary, the sectors with the least unitary impact are the service sectors, except Transportation and communication.

4.2. Embodied Pollution

The values above measure environmental effects per exogenous demand unit so they show the intensity of an economic agent generating pollution. However, they do not inform about the magnitude of the effects because it depends on the size of the demand. Therefore, to identify better which agents generate the highest atmosphere emissions, the embodied pollution global values are obtained from SAMEA built for Aragonese economy. These values are shown in Table 3.

In Table 3, it may be easily observed that the sectors generating the highest embodied pollution to produce goods and services of household and foreign demand are Energy products, agro food industry (comprising Agriculture, Livestock and Food

industry), and the industry sector Transportation material. Three service sectors (Commercial services, Catering and restaurants and Transportation and communication) are significant too by their embodied pollution. On the other hand, the atmosphere emissions generated by Public sector and Saving-Investment are very important being their emission volumes above 4.2% of total emission volume.

Table 3. Global embodied pollution values

		CO ₂ (t)	CH ₄ (t)	N ₂ O (t)	HFC (kg)	PFC (kg)	SF ₆ (kg)	CO ₂ eq (t)
AP1	Agriculture, forest culture and aquiculture	526,293	2,643	2,304	1,217	1	2	1299,237
AP2	Livestock farming;	220,180	56,601	215	1,499	1	2	1479,171
AP3	Energy products	3952,484	4,996	104	205	1	2	4090,148
AP4	Water	36,548	71	2	49	0	0	38,696
AP5	Minerals and metals	20,373	28	1	40	0	0	21,425
AP6	Minerals and no metal products	455,321	189	31	184	0	1	469,521
AP7	Chemical Products	119,947	297	17	16,608	0	1	173,409
AP8	Metal products and equipment	624,021	1,143	52	1,967	69	153	673,177
AP9	Transportation material	1148,944	2,430	83	5,978	22	48	1242,270
AP10	Food, beverage and tobacco	719,647	27,788	1,600	2,444	2	3	1805,345
AP11	Textiles, leather and shoes	57,123	363	16	1,750	0	1	74,261
AP12	Paper and printing items	383,136	752	128	1,316	1	2	441,845
AP13	Wood and Cork (except wood furniture)	54,820	139	45	211	0	0	72,220
AP14	Rubber, plastics and other manufacture	133,320	350	16	4,076	1	3	156,130
AP15	Construction and Engineering	39,930	56	4	94	0	1	42,577
AP16	Reclamation and repairs	966	2	0	3	0	0	1,039
AP17	Commercial services	1072,823	2,879	77	2,109	3	8	1162,633
AP18	Catering and restaurants	558,004	5,504	345	1,251	2	4	783,819
AP19	Transportation and communication	507,157	551	28	367	1	1	528,408
AP20	Credit and insurances	67,437	240	5	49	0	0	74,109
AP21	Property activities	188,141	832	25	556	2	4	214,825
AP22	Private education	36,967	124	5	75	0	0	41,211
AP23	Private health services	68,943	238	18	588	1	1	81,052
AP24	Other sale services	125,500	3,366	29	396	0	1	206,176
AP25	Domestic services	0	0	0	0	0	0	0
AP26	Public education	3,736	13	0	7	0	0	4,148
AP27	Public health services	12,632	58	5	185	0	0	15,764
AP28	Other public services	5,328	136	2	9	0	0	8,760
L	Labor factor	0	0	0	0	0	0	0
K	Capital Factor	0	0	0	0	0	0	0
COM	Companies	267,785	1,533	40	952	4	10	315,074
PUB	Public sector	666,465	7,721	157	5,579	6	14	891,771
S-I	Saving-Investment	452,175	2,293	63	1,365	8	18	523,895

Table 4. Global embodied pollution values per capita

		CO ₂ (kt)	CH ₄ (t)	N ₂ O (t)	HFC (kg)	PFC (kg)	SF ₆ (kg)	CO ₂ Eq (t)
AP1	Agriculture, forest culture and aquaculture	0.4434	0.0022	0.0019	0.0010	0.0000	0.0000	1.0947
AP2	Livestock farming;	0.1855	0.0477	0.0002	0.0013	0.0000	0.0000	1.2463
AP3	Energy products	3.3302	0.0042	0.0001	0.0002	0.0000	0.0000	3.4462
AP4	Water	0.0308	0.0001	0.0000	0.0000	0.0000	0.0000	0.0326
AP5	Minerals and metals	0.0172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0181
AP6	Minerals and no metal products	0.3836	0.0002	0.0000	0.0002	0.0000	0.0000	0.3956
AP7	Chemical Products	0.1011	0.0003	0.0000	0.0140	0.0000	0.0000	0.1461
AP8	Metal products and equipment	0.5258	0.0010	0.0000	0.0017	0.0001	0.0001	0.5672
AP9	Transportation material	0.9681	0.0020	0.0001	0.0050	0.0000	0.0000	1.0467
AP10	Food, beverage and tobacco	0.6064	0.0234	0.0013	0.0021	0.0000	0.0000	1.5211
AP11	Textiles, leather and shoes	0.0481	0.0003	0.0000	0.0015	0.0000	0.0000	0.0626
AP12	Paper and printing items	0.3228	0.0006	0.0001	0.0011	0.0000	0.0000	0.3723
AP13	Wood and Cork (except wood furniture)	0.0462	0.0001	0.0000	0.0002	0.0000	0.0000	0.0609
AP14	Rubber, plastics and other manufacture	0.1123	0.0003	0.0000	0.0034	0.0000	0.0000	0.1316
AP15	Construction and Engineering	0.0336	0.0000	0.0000	0.0001	0.0000	0.0000	0.0359
AP16	Reclamation and repairs	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009
AP17	Commercial services	0.9039	0.0024	0.0001	0.0018	0.0000	0.0000	0.9796
AP18	Catering and restaurants	0.4702	0.0046	0.0003	0.0011	0.0000	0.0000	0.6604
AP19	Transportation and communication	0.4273	0.0005	0.0000	0.0003	0.0000	0.0000	0.4452
AP20	Credit and insurances	0.0568	0.0002	0.0000	0.0000	0.0000	0.0000	0.0624
AP21	Property activities	0.1585	0.0007	0.0000	0.0005	0.0000	0.0000	0.1810
AP22	Private education	0.0311	0.0001	0.0000	0.0001	0.0000	0.0000	0.0347
AP23	Private health services	0.0581	0.0002	0.0000	0.0005	0.0000	0.0000	0.0683
AP24	Other sale services	0.1057	0.0028	0.0000	0.0003	0.0000	0.0000	0.1737
AP25	Domestic services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AP26	Public education	0.0031	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035
AP27	Public health services	0.0106	0.0000	0.0000	0.0002	0.0000	0.0000	0.0133
AP28	Other public services	0.0045	0.0001	0.0000	0.0000	0.0000	0.0000	0.0074
L	Labor factor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	Capital Factor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
COM	Companies	0.2256	0.0013	0.0000	0.0008	0.0000	0.0000	0.2655
PUB	Public sector	0.5615	0.0065	0.0001	0.0047	0.0000	0.0000	0.7514
S-I	Saving-Investment	0.3810	0.0019	0.0001	0.0012	0.0000	0.0000	0.4414
	TOTAL	10.5541	0.1039	0.0046	0.0431	0.0001	0.0002	14.2664

Comparing the embodied pollution unit values and embodied pollution global values, we can see some differences. Minerals and no metal products, Water, and Wood and Cork (except wood furniture) generate important amount of atmosphere emissions to produce one monetary unit of household and foreign demand, however, atmosphere emissions that they generate to produce all household and foreign demand are not so

significant. Similar is for Agriculture and Livestock farming, their embodied pollution global values are significant, however they lose importance with regard to the significance of their unit values because of their lower household and foreign direct demand.

The opposite occurs for the service activities: Catering and restaurants and Commercial services, and for industrial sectors: Food, beverage and tobacco and Transportation material. These activities are not very polluter considering unit values, but they are between the activities that generate the greatest quantity of pollution to produce all household and foreign demand.

Until now, we have analyzed the pollution embodied and direct pollution produced by the economic agents because of the activity of all population. Therefore, to close the analysis and given that it is interesting to know the pollution impact per person in the Aragonese economy and to measure the individual responsibility, per capita values are calculated. The figure of the Aragonese population is obtained from Spanish Statistical Institute. The results are presented in Table 4.

It is very high value, however, from SAMEA we obtain that the 46% of that value is produced outside Aragon, in the foreign regions and countries.

According to the results, Energy products, agro food industry (comprising Agriculture, Livestock and Food industry), and the industry sector Transportation material, with Public sector, Saving-Investment and three services sectors Commercial services, Catering and restaurants and Transportation and communication, are the economic agents that generate the biggest pollution quantity to satisfy the household and foreign demand per capita.

The reason of this, for Food, beverage and tobacco, Commercial services and Catering and restaurants, is the amount of the household demand of those activities. Therefore, to decrease the pollution, it could be interesting approach to discuss environmental policies willing to change consumption behaviours or the production systems of those activities in order to generate lower pollution. The last option is especially for Energy products.

These values per capita provide a clear representation of the impact on the environment per Aragonese citizen. In the Table 4, we can observe that CO₂ eq. emissions caused by the different productive activities to satisfy household and foreign demand and by the institutions as a result of household and foreign expenditure are 14.27 t per capita.

5. Conclusions

The objective of this paper is to show how input-output methodology can be useful in the analysis of environmental impacts in a regional context. More concretely, our main aim has been to analyse the impact that the Aragonese economy has on the close environment when it obtains the necessary products to satisfy the final demand of domestic households and foreign sector.

Thus, from the SAMEA, that lets us to know straight which economic agents produce directly major atmosphere emissions, we have identified economic agents that are significant because of their direct and indirect pollution, that is to say, not polluting in their direct activity but forcing other sectors to pollute. Moreover, we have obtained

which sectors generate directly and indirectly, the greatest quantity of pollution, in intensive terms and in global terms.

According to the unitary pollution values, we have proved that the unitary pollution is concentrated in very few economic agents, and each one of them is significant in different kind of emissions.

We have also proved that the production sectors that generate more atmospheric pollution to produce goods and services associated to the households and foreign demand are Energy products and agro food industry. Therefore, it would be interested to consider the development of solar and wind energy, because of adequate Aragonese features for these energy kinds.

Food industry, Catering and restaurants, and Commercial services, generate directly and indirectly important atmospheric emissions as a consequence of the amount of the household demand on these activities.

For this reason, there is a link between the environmental impact and the households' consumption behaviors. It would be an interesting approach to discuss environmental policies willing to change consumption behaviors.

Finally, we have seen that the household expenditure on goods and services is not the only one that generates pollution, but that household expenditure destined to Public sector and saving generates pollution, too.

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Figure 1. Environmental landscape for CO₂ emissions in Aragon

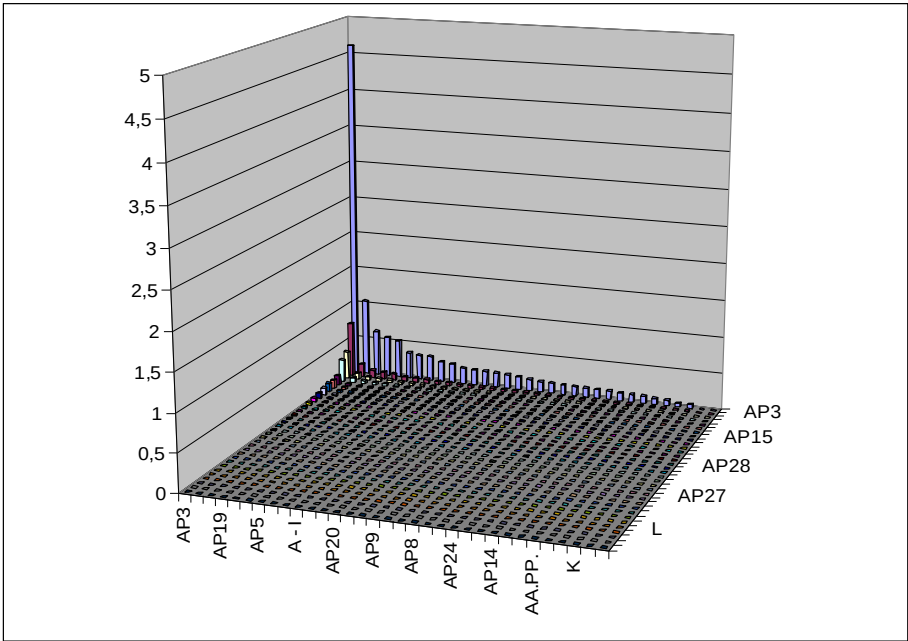


Figure 2. Environmental landscape for CH₄ emissions in Aragon

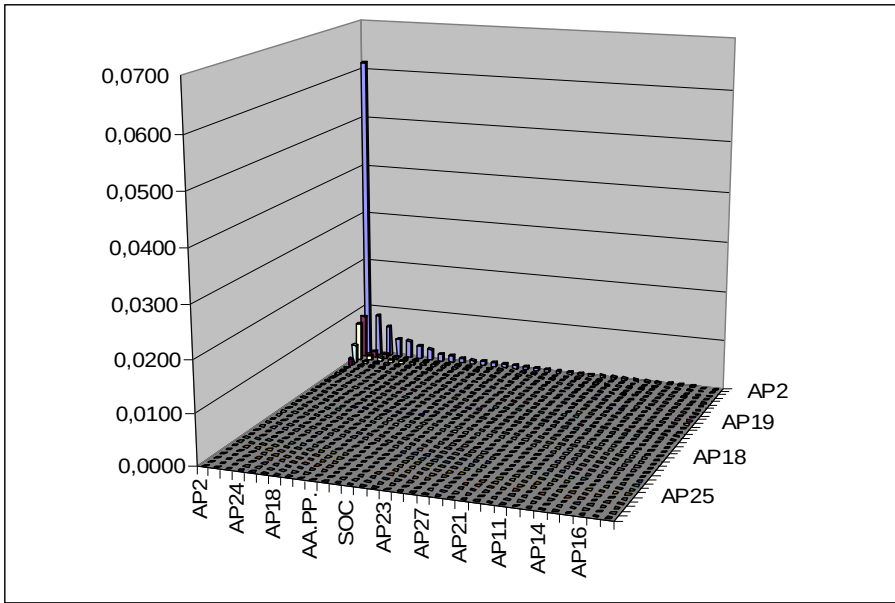


Figure 3. Environmental landscape for N₂O emissions in Aragon

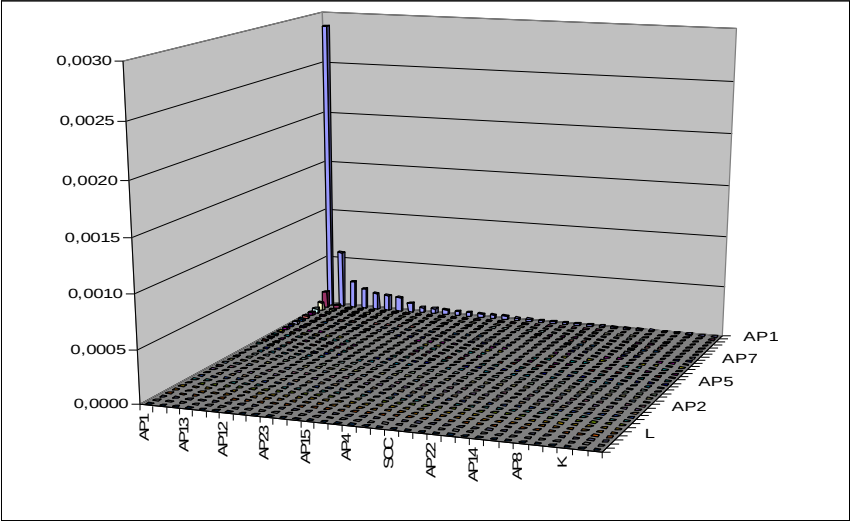


Figure 4. Environmental landscape for equivalent CO₂ emissions in Aragon

