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Assessing the socio-economic impacts of drought in the Ebro River Basin

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Abstract

Droughts can be defined as a significant reduction in water resources during a long period of time in a large spatial area which leads to negative consequences. These episodes have traditionally been regarded as an agricultural problem and thus their economic impacts have been considered limited to the rural environments. However, current water uses cover a broader scope of economic activity and water deficits generate impacts in a greater number of sectors. The specific objective of this paper is to estimate the direct and indirect economic impacts of a drought episode in the Ebro River Basin, using available statistical information within an *Input-Output* framework. Direct impacts are assessed for the two main sectors affected by this drought, agriculture and energy production, and with these effects, the indirect impacts on the wider economic activity are derived for the whole river basin. Results show that this climatic episode resulted in a direct gross added value loss of over €482 million in the two sectors considered with an additional induced production loss of €377 million. This reduction in activity resulted also in a reduction of over 11.000 jobs.

Additional key words: direct effects, economic valuation, indirect effects, *Input-Output* models.

Resumen

Análisis de los efectos socioeconómicos de la sequía en la cuenca del Ebro

La sequía es un fenómeno caracterizado por una disminución coyuntural significativa de los recursos hídricos durante un período prolongado, en un territorio extenso y con consecuencias adversas. Tradicionalmente ha sido considerada como un problema fundamentalmente agrario, de manera que sus implicaciones se han buscado en el ámbito rural, pero la amplitud e importancia del uso de los recursos hídricos en la sociedad actual conlleva situaciones de déficit y crea un abanico de problemas muy graves. Los objetivos específicos del estudio son, a partir de la información estadística secundaria disponible, estimar el impacto económico directo de la sequía en el año 2005 sobre la producción agraria y energética en la cuenca del Ebro y, en segundo lugar, y mediante la utilización del Marco *Input-Ouput* (MIO), estimar los efectos indirectos de la sequía sobre la producción y el empleo en el conjunto de la economía de la cuenca. Los resultados muestran como este episodio ha supuesto un impacto directo de más de 482 millones € de valor añadido bruto en el sistema económico, al que se ha podido asociar una pérdida de producción de 377 millones €. Esta disminución lleva asociada también la destrucción de más de 11.000 empleos.

Palabras clave adicionales:, efectos directos, efectos indirectos, modelos *Input-Output,* valoración económica.

Introduction

Drought periods can be defined as significant water shortages spanning during sufficiently long periods of time, in a vast region and with adverse socio-economic and environmental consequences. Drought is a normal, recurrent climate phenomenon which happens in all climatic regions and is characterized by a slow and progressive development. This means that drought only becomes evident when the problem is already there. Droughts in Spain

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Abbreviations used: CAP (common agricultural policy), CGE (computable general equilibrium), CNAE (clasificación nacional de actividades económicas), GAV (gross added value), GDP (gross domestic product), IOF (input-output framework).

are not a recent phenomenon, already different medieval chronicles speak of periods of low rainfall. Since then, Spain has suffered insistently the rigors of this natural phenomenon. The last drought period started at the end of 2004, it developed in a severe, generalized way throughout the country in 2005 and still continues in some areas. According to the National Institute of Meteorology, the year 2005 presented a marked deficit in rainfall, with January 2005 as one of the driest months in the last fifty years.

The analyses of the impacts of droughts have traditionally been undertaken considering droughts mainly an agricultural problem, with research focused on rural areas. However, at this moment, considering the incidence of drought only on agricultural production would miss other important impacts in the wider economic activity. Therefore, the aim of this paper is twofold: first, to evaluate the direct economic impact of the drought in 2005 on economic activity[1] in the Ebro basin and, second, by using the supply model of the *Input-Output Framework* (IOF); to estimate the indirect effects of drought on production and employment on the whole economy of the Ebro basin. The rest of the paper is organized as follows: after this introduction, the main direct effects of drought on the Ebro basin are analysed through the evolution of the agricultural and energy productions, and their contribution to gross added value (GAV). The third section presents the IOF theory, illustrating by matrix algebra how the production and employment vectors are obtained from a change in final demand or added value. The fourth section shows the empirical results of the impact that drought caused to the production and employment of the economy in the Ebro basin in 2005. The paper concludes with a summary and main conclusions from the analysis made.

Direct effects of the 2005 drought in the Ebro basin

As a first approach to estimating the economic impact of the 2005 drought, the evolution of GAV in the Ebro region and the contribution of the different productive sectors can be analysed[2]. According to the available data from the National Institute of Statistics (INE, 2007), the economy in the Ebro region has experienced a continuous period of growth during the period 2000-2005, with an accumulated growth of almost 60%, figures higher than average for Spain as a whole.

As far as the purpose of this paper is concerned, the agriculture and energy activities in the Ebro region contributed to about 5% of the regional GAV from 2000 to 2004. Along that period, their contribution to the annual GAV presented a slightly decreasing tendency, with a minimum of 4.3% of the Ebro region GAV in 2005. The agricultural sector contributed to the GAV with 2.9% as average in 2000-04, decreasing to 2.3% regional GAV in 2005. On the other side, the energy sector[3] presented a more constant contribution to GAV in the time, decreasing from 2.1% in average for the period 2000-04 to 2.0% in 2005.

Considering the evolution in time of these magnitudes, in constant Euros of 2005, it can be observed that the GAV of these has increased, although at lower rates than in other branches of activity such as construction or services. From 2000 to 2004, the contribution of these two sectors to GAV increased from €6,196 million to 8,567 million in 2004, to go down to €8,388 million in 2005. That is, in 2005 there was a global decrease of €180 million, with respect to the previous year. However, data seems to indicate that the drought impact in 2005 was important overall in the agricultural sector, for its contribution to GAV decreased by €418 million in 2005 with respect to 2004, while the energy production sector increased by €238 million in the same period.

Total agricultural production in the Ebro region accounted for €7,800 million which can be divided approximately in half between crop and animal productions. As water scarcity affects crop production directly we focus on the analysis of this sector in the rest of the paper[4]. Out of the approximately 2.4 million ha cultivated, almost one third is irrigated. The cultivated surface

[1] The impacts are focused on those sectors where more information is available and impacts have been more severe (agriculture and energy production). It is true that drought can imply some cost in other sectors (fires, health, tourism, etc), but it is also true that the impact can be calculated using ecosystemic services approaches (Barrio *et al*., 2007) or value of the statistical life (Vicusi and Aldy, 2003).

[2] Given the absence of economic or social statistics at river basin scale, in this work, the "Ebro region" is considered to comprise the NUTS II regions of Navarra, La Rioja, Aragón and Cataluña.

[3] Although we use the term energy sector, it should be taken into account that data is only used for its production phase. The impact on transport and distribution is not evaluated directly but through the indirect effect derived from the application of the IOF.

[4] Animal production can be affected due too due to scarcity in feedstuffs production, however, this effect is taken into account when we estimate the induced effects using the IOF.

in the Ebro region decreased 335,000 ha during the period 2000-2005. In 2005, approximately 80,000 ha less than in 2004 were cultivated. Of all crops, three main groups (cereals, forages and fruit orchards) represent 80% of the total surface. For the 2000-2004 period, total cereals accounted for 1,435,000 ha, with a very stable pattern throughout the whole period, stability that was broken in 2005, when there was a decrease of 36,000 ha with respect to the previous year. Forages, mainly alfalfa, occupied an average of 204,000 ha in that same period, presenting a slightly decreasing tendency and reducing its surface in 2005 by almost 8,500 ha with respect to the previous year. Finally, fruits orchards occupied an average of 280,000 in the same period, presenting a similar decreasing tendency which was further reinforced in 2005 by 7,800 ha with respect to the previous year.

The remaining crops have a lower relative importance, although a similar decreasing tendency has been detected for vegetables and industrial crops while permanent crops (vineyard and olive grove) remain constant and pulses gain surface during this period. With this overall pattern in mind, and in order to quantify the direct economic impact of drought on the agricultural sector, Table 1 shows the value of average agricultural production for the period 2000-04 as well as the value of the agricultural production in 2005, both in constant Euros of 2005. The figures show that the value of the total crop production in the Ebro region was reduced from €3,834 million in average for 2000-04 to €3,294 million in 2005. Therefore, *ceteris paribus* the loss of total crop production which can be inputted to the drought episode for 2005 can be quantified as reaching €540 million.

In order to translate the loss of production into loss of added value, additional information must be obtained. Using the data on agricultural macro-magnitudes which can be found in the accounts for agricultural production[5], intermediate consumption can be estimated as approximately 25% of the total agricultural production. This figure must be deducted from total production to obtain an estimate of GAV and thus, the GAV at basic prices, or agricultural quasi-rent, loss due to the drought episode of 2005 can be estimated as €405 million.

As far as the energy sector is concerned, the same approach as above has been followed. Table 2 summarizes the production of electricity in the Ebro river basin according to its origin using data from "*Red Eléctrica de España*" (REE, several years), the national agency for power transmission and the operation of electricity systems. The effect of the drought affects fundamentally the electricity production from hydropower plants. From the analysis of these figures, energy production has grown steadily with hydropower accounting approximately for 15% of total electricity production during the whole period, with the exception of 2005, when its contribution was dramatically reduced to less than 10%. However, while hydropower electricity originated in the Ebro River Basin accounted for approximately 21% of total national production, in 2005 its share rose to 26.2%, indicating that the drought had a stronger effect on hydropower production in other Spanish regions.

Next, and in the same way as it has been done for the agricultural sector, the direct economic impact of drought on the energy sector can be quantified from the changes in physical production. Using the data from Table 2, the average value of the hydroelectric production in the Ebro basin for the period 2000-04 compared with that of 2005 shows a reduction of 1,571 GWh. Considering that the average price in the production market for that year[6] was 6.242 cents of € kWh^{-1}, the value of the total hydroelectric production in the Ebro region decreased from €411.8 million to €313.8 million[7]. Therefore, again, *ceteris paribus*, the loss of hydroelectric energy total production due to drought in that year can be assessed to reach €98 million. Once more, the analysis of the economic magnitudes of the hydroelectric[8] production allows verifying that the inter-

[5] This source allows identifying the composition of agricultural production (*i.e.* intermediate consumptions, taxes and subsidies, profit, etc...) using SEC-95 standards (Carrasco-Canals, 1999). Up to year 2000 these were published by the former Ministry of Agriculture and now most of the Spanish regions keep updating them.

[6] For further information, see REE (2005).

[7] Electricity from hydropower origin usually enters the market at marginal prices which are higher than average ones. However, there is no data availability with regards to the exact price at which the electricity generation loss took place. Nevertheless, an estimate of the maximum error that can be attached to this use of average instead of marginal prices can be obtained. The difference between weighted average and maximum prices paid for electricity in 2005 is 0.0246 € kwh^{-1} (OMEL, 2005). This means that if all electricity from hydro power had been sold at maximum prices the impact would have been 39% higher. Therefore, our estimate must be considered a conservative one.

[8] Considering the lack of official data at this level of sub-sector disintegration, we base our analysis on the available estimations for Andalucía provided by Martín *et al*. (2006).

Table 1. Agricultural production and prices for the Ebro region (2000-2005)

Crop group	Crop	Average production 2000-04 (Mg)	Production 2005 (Mg)	Price 2005 (€/100 kg)	Average production 2000-04 (€)	Average production 2005 (€)
Cereals	Wheat	1,255,889	989,868	14.0	175,322,076	138,185,573
	Barley	2,100,084	1,170,944	13.3	278,891,182	155,501,363
	Rice	440,472	186,224	19.1	84,306,357	35,643,330
	Oats	107,048	85,608	14.2	15,147,320	12,113,532
	Rye	11,917	5,943	13.1	1,564,676	780,316
	Corn	1,323,342	1,036,289	13.5	178,651,197	139,899,015
	Sorghum	18,020	9,518	13.4	2,418,311	1,277,316
Pulses	Vetch	9,924	5,509	19.2	1,908,308	1,059,381
	Dry broad beans	4,190	5,472	22.0	922,594	1,204,934
	Dry beans	1,183	1,081	146.2	1,729,428	1,580,314
	Yeros	7,546	3,165	14.9	1,124,354	471,585
Tubers	Potatoes	270,694	192,766	17.2	46,505,195	33,117,199
Industrial crops	Sunflowers	59,969	26,808	25.3	15,142,122	6,769,020
	Sugar beet	117,639	150,707	5.5	6,470,156	8,288,885
Fodder crops	Corn	474,531	362,298	13.5	64,061,631	48,910,230
	Alfalfa	8,266,427	6,717,982	12.5	1,034,956,610	841,091,346
	Vetch	197,746	94,471	11.8	23,353,803	11,157,025
Vegetables	Sprouts	43,074	51,180	53.0	22,807,683	27,099,810
	Asparagus	7,977	5,056	166.8	13,309,494	8,435,430
	Lettuce	97,294	77,743	51.1	49,736,693	39,742,222
	Spinach	20,689	19,098	61.9	12,804,670	11,819,752
	Melon	18,605	15,092	25.8	4,807,480	3,899,773
	Tomato	369,652	357,462	52.2	192,921,170	186,559,418
	Pepper	35,726	38,546	67.9	24,243,392	26,157,316
	Artichoke	52,356	25,589	62.5	32,711,904	15,988,007
	Cauliflower	141,312	133,756	44.6	62,968,627	59,601,674
	Onion	107,776	96,547	15.9	17,082,559	15,302,700
	Green beans	49,099	42,467	148.4	72,872,736	63,029,521
	Green peas	39,620	26,324	59.9	23,740,064	15,773,341
	Green broad beans	12,014	5,228	102.8	12,349,981	5,374,384
Fruit trees	Apple	545,786	541,928	25.4	138,356,700	137,378,748
	Pear	525,864	519,107	39.1	205,770,505	203,126,569
	Apricot	11,056	15,290	99.1	10,956,694	15,152,390
	Cherry	50,046	40,476	174.1	87,115,072	70,456,573
	Peach	580,494	686,079	46.3	268,710,673	317,585,969
	Plum	27,581	25,325	36.7	10,108,510	9,281,613
	Almond	57,480	65,388	145.0	83,346,290	94,812,600
	Hazelnut	20,485	22,327	242.6	49,701,677	54,169,767
Wine	Grapevine	1,063,148	1,005,743	37.0	393,364,810	372,124,910
Olive groves	Olives	190,405	177,374	58.9	112,205,549	104,526,498
TOTAL		18,734,159	15,037,778		3,834,468,254	3,294,449,348

Source: Own elaboration using data from Agrofood Statistics Yearbook (MAPA, several years)).

mediate consumptions in this productive activity account for approximately 21.5% of hydropower production. Thus, the loss of GAV at basic prices due to 2005 drought would reach €77 million.

Table 2. Electricity production by source in the Ebro river basin 2000-05 (GWh)

	2000	2001	2002	2003	2004	2005
Hydropower	5,766	7,208	5,189	7,795	7,031	5,027
Nuclear	20,837	19,854	20,926	20,537	19,373	19,448
Thermal	8,290	6,221	9,196	10,140	12,490	16,367
Wind power	1,794	2,576	3,569	4,270	5,676	7,070
Other renewable	118	90	225	370	347	389
Non-renewable	4,036	4,034	4,160	4,162	4,575	4,747
TOTAL	40,841	39,983	43,265	47,273	49,492	53,048

Source: Own elaboration based on Red Eléctrica Española (REE, several years)

Expanding the effects: supply and demand models in the *Input-Output* frame

In order to estimate the wider economic impacts of the direct effects of the drought in the Ebro River Basin, the *Input-Output* framework is used. This section presents how to calculate the production and employment effect vectors for the whole economy starting from a change in the final demand or in the GAV, as calculated in the previous section.

The basic hypothesis in this analysis is to consider that the 2005 drought produced a direct effect which is equivalent to the decrease of the agricultural and energy productions. This in turn can be considered a GAV decrease in the economy of the Ebro basin with respect to the potential GAV that could have been reached in the case that situation would not have happened (*i.e.* there had been no drought). The drought also had an indirect macroeconomic effect because, if absent, probably production and employment would have been more important in another branches besides agriculture and energy. The reason is that all the branches in production generate intermediate consumptions in other branches in order to be able to carry out their own productive activity. This means that the quantitative impact of drought is spread throughout the whole economy of the Ebro region as well as outside the region, as some intermediate inputs or consumptions can be imported from other regions or foreign countries.

In this way, expanding irrigation surface or intensifying the hydropower production affects directly the production of both branches, but also indirectly the productive branches that supply them with the intermediate consumptions, such as oil or equipment maintenance and repair services. Thus, a number of productive activity branches, in this case agriculture and energy, suffer a demand shock or an added value one, which will affect branches which supply the corresponding inputs, thus producing a linked process of economic effects on production and employment inside and outside this specific area studied.

The quantitative estimation of the increase in production and employment caused by a shock on the final demand of an specific sector in the IOF context can be undertaken using the demand model. The model replicates how a variation in a component of the final demand causes economic transactions between different activity branches, thus producing a succession of linked economic impacts, which in the end produces a multiplying effect on production and employment in the overall economic structure of the region. In conclusion, this particular analysis provides a quantitative image of some of the interdependencies that take place in an economic system, with its major contribution being that it accounts for all the relationships between the different branches. To undertake this analysis, the 2003 IOF is used (CEPREDE, 2007). This IOF considers the economy of the Ebro region in 26 branches of activity[9].

The information from the IOF symmetric table is used for the implementation of the IOF demand model. The symmetric table was developed *ad hoc* for this study using data for La Rioja, Navarra, Aragón and Catalonia. This table reflects each branch as a column and a row of the IOF. Data from the columns reflect the *inputs* of the productive process of the corresponding branch, while data the rows refer to the outputs of the productions of each branch (intermediate consumptions). By definition, the total intermediate consumptions used by all the branches (sum by columns) is equal

[9] Each branch consists of one or more codes of the "*Clasificación Nacional de Actividades Económicas*" (CNAE-93).

to the total outputs (sum by rows) of products for intermediate use of the remaining branches. However, this equity does not occur necessarily for branches considered individually.

The *demand model* relates the final demands and the production levels needed to fulfil them. If alternative demand levels are introduced into the model, the productions for each branch needed to fulfil that final demand can be calculated. Each branch has to produce that final demand objective and the intermediate products required by other branches to reach the new final demand. When the number of branches increases, this problem can be solved by the algorithm known as inverse of the Leontief's matrix:

$$X = (1 - A)^{-1} D \qquad [1]$$

being X the column vector of productions at basic prices for each branch (to be calculated), $(1\text{-}A)^{-1}$ the inverse of the Leontief's matrix, $(1\text{-}A)$ and D the column vector of the final demands.

However, the *demand model* of Leontief was specifically conceived to analyse the effects that a change in the final demand of one or several branches have on their production. It is a demand-driven model, where demand is considered determined in an exogenous way and based on the internal coherence between branches provided by the matrix of technical coefficients. The characteristics of the IOF, evidence the possibility of considering an alternative model to that of demand. In this alternative model, the coefficients are not determined by columns but by rows, market or distribution coefficients instead of technical ones are obtained, and the strategic variable determined exogenously to the model is added value instead of final demand. Thus what this approach does is "rotate" the way the IOF symmetric table is looked at. This approach is known as as Leontief's *supply model* or Ghosh's model, after who proposed this new approach (Ghosh, 1958; Dietzembacher, 1997).

The symmetric table considering the relationships between columns can be express for any j branch as:

$$X_j = x_{1j} + x_{2j} + \ldots + x_{nj} AV_j \qquad [2]$$

and, in matrix terms as:

$$X' = x_{ij} + AV' \qquad [3]$$

The new b_{ij} coefficients now represent the output of branch i which is used by branch j and can be defined as $b_{ij} = x_{ij} / X_i$. Substituting in [3] and expressing it in matrix terms, the following expression is obtained:

$$X' = BX' + AV' \qquad [4]$$

Which can be re-written as,

$$X'(1 - B) = AV' \qquad [5]$$

post-multiplying both terms of the equation by $(1\text{-}B)^{-1}$ the final expression of the supply model is obtained:

$$X' = AV'(1 - B)^{-1} \qquad [6]$$

Denoting δ_{ij} the elements of the inverse matrix $(1 - B)^{-1}$, the production of sector X_j is now a combination of the added values of the different sectors:

$$X_j = \delta_{i1} AV_1 + \delta_{i2} AV_2 + \ldots + \delta_{in} AV_n \qquad [7]$$

Each element b_{ij} of the matrix $(1 - B)^{-1}$ can be interpreted as the production increase of branch j of the matrix when there is an increase in the added value of branch i. Therefore, the sum of row i of this matrix represents the increase in the production of all the branches when the added value of the branch i increases.

As an additional feature of the IOF, once the inverse matrixes of Leontief or Ghosh are calculated, different situations can be analysed. Of particular interest for this study is the estimation of the employment requirements by branches when faced with a production increase. An increase of the production in one or more branches induces the creation of employment in the same branch (L_j). The size of this effect is obtained from the vector row of *direct coefficients of employment* (l_j), defined as the quantity of employment needed for each production unit, using following expression:

$$L_j = \hat{l}(1 - A)^{-1} D \qquad [8]$$

where $\hat{l}$ is the diagonal matrix of the direct coefficients of employment, either in physical or monetary terms, and D the vector column of final demand. The result of this calculation is the number of employments generated in each branch when faced with an increase in the final demand, and adding up for all branches, the global employment generated in the whole economy as a consequence of the total production increase.

The impact of drought on production and employment

As mentioned above, the 2003 Ebro IOF follows SEC-95 regulations and guidelines (Eurostat, 1996), with desegregation level of 26 activity branches and based on 2003 data. The supply model can be estimated from the matrix of distribution coefficients (B) of the Ebro IOF, and is used for the elaboration of the Ghosh' matrix (1-B) and its corresponding inverse matrix $(1\text{-}B)^{-1}$. These coefficients are the multipliers which are then applied to the variations of the added values (*AV)* and allow estimating both, the total production (X) and the employment (L) lost at regional level as well as their distribution between each one of the 26 productive activity branches considered.

The application of the supply model $[X = AV\,(1 - B)^{-1}]$ with the economic data of the 2005 drought requires, however, some adjustments as well as some starting hypothesis which are stated below:

- First, concerning the evaluation criteria, the applicable national accounting regulations must be fulfilled (SEC-95). These regulations establish that production has to be evaluated at *basic prices*. This concept has already been presented, and from a supply point of view would be the income obtained per each unit of product. In this sense, the data presented for the direct effects of the drought, €482 million as final demand not met in 2005, correspond to the concept of *basic prices* and therefore do not incorporate either the margins or the taxes on the products net of subsidies. Therefore, they can be used directly in the application of the demand model of the IOF.
- Second, in order to consider *purchase prices* or market prices when starting from *basic prices*, it is necessary to add to these magnitudes the margins and net taxes on the products. According to the data of the regional accounting for the Ebro region, these represent about 10% of the regional gross domestic product (GDP).
- Third, a part of the total good and services supply for each branch can come from imports (outside the considered area). Consequently, if the objective is to estimate the effects of drought exclusively on the Ebro region, the matrix of internal coefficients of distribution (B_{int}) should be used instead of the matrix of total coefficients of distribution (B_{tot}) that would quantify the total effects on the production inside and outside the region.
- Last, the estimation of the negative impact of drought on total production, employment as well as on the participation of the GDP in the Ebro region in 2005 is obtained by adding up the direct and indirect productions obtained from the model for each branch of activity.

Under these hypotheses, the application of the Ghosh' offer model is possible. The results provide an estimate of the production increase that would have been generated as a result of an increase of the added value due to specific *shocks* in the primary and energetic sectors, reflecting the levels of production achievable in the absence of drought. In particular, the model permits analyzing the indirect effects on the regional and extra-regional total production and on employment in the different branches of activity when considering an increase of the added value in the Ebro region of €482 million, 405 of which correspond to the agricultural sector and 77 to the energy one. The results of this estimation are given in Table 3.

The results presented allow identifying some major impacts. Total production, inside and outside the Ebro region, would have had an increase of more than €478 million in order to cover an increase of €482 million in the AV of the agricultural and energy sectors. That is, the indirect effects or the dragging capacity of production on other branches not directly related with the initial increase represent almost 100% of the direct effect on the GAV. This means that given the interrelations of these two branches with the remaining global economy, the indirect effects are equivalent in absolute terms to the amount of the direct effects. Although this result might seem surprisingly high when compared with previous studies applying the IOF to the agricultural sector (Iráizoz and Rapún, 1999; Polo and Valle, 2002) several reasons explain this difference. The approach used in this paper considers both impacts inside and outside the studied regions while both cited studies did not include impacts outside the region. Additionally, the results reported here add the impacts of the energy generation sector to those of agriculture while the cited studies only consider agriculture. Last, there is a methodological difference too, as this paper uses focuses on added value (supply or Ghosh model) while the other focus on production (demand or Leontief model).

Additionally, the model allows obtaining some insight on how these effects are spatially distributed, as from the IOF, effects inside and outside the area for which the IOF has been developed can be calculated. This is done by using the total coefficients of distribu-

Table 3. Direct and indirect effects on production of an increase of the gross added value (GAV) in the agricultural and energy sectors inside the Ebro region (year 2005)

Activity branch	Direct effects on GAV (10^6 €)	Indirect effects on production effects (10^6 €)			
			Inside the Ebro Region		
		Total	Total	Agriculture	Energy
1- Agriculture, forestry and fisheries	405.0	36.3	35.49	33.20	2.28
2- Mining	0.0	0.7	0.47	0.04	0.43
3- Agrofood industry	0.0	237.0	202.80	199.47	3.33
4- Textile and clothing industries	0.0	8.0	3.40	2.02	1.38
5- Leather and footwear industries	0.0	1.8	0.52	0.33	0.19
6- Wood and cork industries	0.0	5.3	0.89	0.48	0.41
7- Paper mills and publishing	0.0	12.3	8.46	4.82	3.65
8- Chemistry industries	0.0	17.3	7.95	1.70	6.25
9- Plastics and rubber industries	0.0	3.6	2.46	1.00	1.47
10- Non-metal mineral industries	0.0	3.4	2.41	0.34	2.07
11- Metallurgy	0.0	5.5	3.06	1.11	1.95
12- Mechanic and mechanical equipments production	0.0	2.8	1.80	0.64	1.16
13- Electric, electronic and optic materials and equipment	0.0	3.8	2.51	0.77	1.74
14- Transport material production	0.0	6.4	3.48	0.94	2.53
15- Other industries	0.0	3.0	1.52	0.85	0.67
16- Energy production and distribution, gas and water	77.0	22.3	16.58	0.59	15.99
17- Building	0.0	10.5	9.90	7.78	2.12
18- Motor vehicle sales and repairs	0.0	19.9	16.40	11.66	4.73
19- Catering services	0.0	41.0	33.97	31.51	2.46
20- Transport, logistics and communications	0.0	12.9	4.16	0.96	3.20
21- Financial activities	0.0	1.3	1.00	0.37	0.63
22- Real state and business services	0.0	5.6	4.01	1.90	2.11
23- Public administration	0.0	3.9	3.32	1.07	2.25
24- Education	0.0	1.9	1.60	0.65	0.95
25- Health services	0.0	3.4	2.39	1.52	0.87
26- Other professional and personal services	0.0	8.5	7.16	5.79	1.37
TOTAL	482.0	478.2	377.70	311.54	66.16

Source: own elaboration

tion and the interior coefficients of distribution. The results of the latter are presented in the last three columns of Table 3.

From the analysis of these results it can be verified that most of the indirect impact of the increase in production needed to cover the direct impact of the drought would be concentrated in the same Ebro region, generating €377 from the 478 million, close to 80% of the total potential production. This means that the increase of the extra-regional production from an increase of the added value of €482 million in the Ebro region would be restricted to €100 million.

Concentrating on the analysis of those branches indirectly more affected by this increase of the added value, it can be seen that only five of them represent 80% of the €377 million of total potential production: agrofood industry (€237 million); agriculture, forestry and fishing (€36.3 million); catering business (€41.0 million); energy industry, distribution of energy, gas and water (€22.3 million) and market and repair of motor vehicles

(€19.9 million). These results also point at the primary sector, and in general at the whole agrofood chain of the region, as the most direct and indirectly affected by drought.

As mentioned above, the *input-output model* of supply also permits estimating the impact of an increase of the added value on employment in the region. In order to quantify that impact, employment was estimated by activity branches in the Ebro region for 2005; the direct coefficients of employment were also calculated for each one of the 26 activity branches of the Ebro IOF and a diagonal matrix of employment coefficients was constructed. Through the expression $L_j = \hat{l}(1 - A)^{-1}$, the number of potential employments in each branch and in the total economy as a consequence of the increases in the final demand and in the total production can be estimated as shown in Table 4.

The global results show that the relationship between employment and drought in 2005 is important, with a total loss of 11,275 jobs in that year. Concerning their distribution by activity branches, three parts of the agrofood chain account for more than 86% of this employment destruction by drought: agriculture, forestry and fishing (8,094 jobs); agrofood industry (1,229 jobs) and

Table 4. Estimated employment effects derived from the drought in the Ebro Region

	Activity branch	Total production (10^3 €)	Total employment (jobs)	Employment loss (jobs)	Due to…	
					Agricultural sector (jobs)	Energy sector (jobs)
1	Agriculture, forestry and fisheries	9,911,860	182,121	8,094	8,052	42
2	Mining	941,451	7,904	4	0	4
3	Agrofood industry	22,014,358	133,355	1,229	1,208	20
4	Textile and clothing industries	9,887,027	95,376	33	19	13
5	Leather and footwear industries	2,357,140	23,844	5	3	2
6	Wood and cork industries	2,582,581	24,775	8	5	4
7	Paper mills and publishing	13,383,737	89,224	56	32	24
8	Chemistry industries	20,083,935	89,817	36	8	28
9	Plastics and rubber industries	6,783,958	52,921	19	8	11
10	Non-metal mineral industries	5,940,043	43,399	18	2	15
11	Metallurgy	17,440,381	145,049	25	9	16
12	Mechanic and mechanical equipments production	9,936,311	92,731	17	6	11
13	Electric, electronic and optic materials and equipment	14,654,112	74,769	13	4	9
14	Transport material production	27,515,457	120,131	15	4	11
15	Other industries	6,690,135	70,023	16	9	7
16	Energy production and distribution, gas and water	11,198,882	17,603	147	1	146
17	Building	34,781,556	489,116	139	109	30
18	Motor vehicle sales and repairs	30,650,076	697,265	373	265	108
19	Catering services	20,964,046	289,686	469	435	34
20	Transport, logistics and communications	24,894,197	262,709	44	10	34
21	Financial activities	11,763,455	93,844	8	3	5
22	Real state and business services	38,399,796	436,643	46	22	24
23	Public administration	11,283,546	204,467	60	19	41
24	Education	7,947,525	221,793	45	18	26
25	Health services	11,816,832	289,996	59	37	21
26	Other professional and personal services	11,008,238	458,530	298	241	57
	TOTAL	384,830,636	4,707,090	11,275	10,532	743

Source: own elaboration

catering business (469 jobs), while the change in employment in energy is smaller (147 jobs).

Assessing the relative magnitude of the effects of the agricultural and energy sectors, it can be seen that that the agricultural sector is responsible for 10,532 of the 11,275 jobs lost, losses which are concentrated in the agricultural, forestry and fisheries sector (8,052 jobs), agrofood industry (1,208 jobs) and catering business (435 jobs) that as a whole represent 92%. On the other side, the loss of employment associated with the lower energy production is just 743 jobs, approximately 6.6% of the global employment loss recorded due to drought. From the total jobs losses, 146 are in the energy branch and the remaining ones are distributed more or less equally among the remaining productive branches.

Summarizing, the results on impacts on employment are coherent with the economic structure of the different sectors. The agricultural sector is not particularly involved with the remaining branches of economic activity and is rather intensive in labour its productivity is relatively low. The opposite is observed in the energy branch, more related with the remaining branches, with low labour intensity and with a much higher productivity.

Conclusions

This paper has presented an estimate of the economic impacts of drought using an IOF approach in the Ebro river basin. The *input-output* framework is a valuable approach to quantify the impact that this phenomena has had on one Spanish region during a certain period. The results allow deriving some conclusions, both from a result and a methodological point of view. From the results point of view, the overall effects of the drought, both direct and indirect, on GVA, production and in employment terms are summarised in Table 5. Indirect effects are concentrated in the agrofood industry, agriculture, and catering business that as a whole lost a total of €272 million. Therefore, the whole regional agrofood chain is the most direct and indirectly affected sector by climate change in the Ebro basin. As far as the indirect effects on production of the energy sector, these are quantitatively less important, and are distributed among practically all the considered branches of activity. In terms of employment effects, three steps of the agrofood chain account for more than 86% of that employment loss: agriculture, forestry and fishery; agrofood industry and catering business; the employment effects derived from the energy branch are also less significant.

From a methodological point of view, the proposed approach allows to obtain reliable estimates of the effects of drought in 2005, based upon 2005 observations and 2003 input-output tables. Nonetheless, the impacts presented must still be considered a conservative estimate of the overall effect. By enlarging the range of sectors and/or shocks, a more comprehensive view of the impact of droughts could be achieved (*i.e.* changes in the tourist flows due to less nival resources, etc.). In particular, to be able to get the full picture impacts on other sectors for which secondary data is not available should also be estimated. In this sense, drought can imply costs derived from increased number of fires and burnt areas, increased health problems or reduced tourist activity. There are available methodologies to estimate these impacts such as ecosystemic services approaches (Barrio *et al.,* 2007) or value of the statistical life (Vicusi and Aldy, 2003). This is an area of future research which goes beyond the objectives of this paper. Moreover, other longer drought periods could show different effects patterns (*i.e.* 1992-1995). However, that particular drought also coincided with the implementation of a radical agricultural policy change (McSharry reform) which would make attributing changes only to drought more complicated. In that sense, although the Common Agricultural Policy (CAP) also suffered a radical reform in 2003 (CAP Mid-term review) its implementation in Spain did not occur until 2006 (Atance, 2006) and therefore does not present a problem in our analysis.

Table 5. Summary of estimates of the economic impacts attributable to the 2005 drought in the Ebro Region

	Attributable to agricultural sector	Attributable to energy sector	Total
Direct effects on gross added value (10^6 €)	405.00	77.00	482.00
Indirect effects on production (10^6 €)	311.54	66.16	377.70
Effects on employment (nº of jobs)	10,532.00	743.00	11,275.00

An additional value of approaches such as the one proposed here is the role they can play in order to obtain a complementary estimate of climate change impacts. The impact of the climate change is probably one of the most important topics of discussion at international level. A great part of the importance given to this problem comes from the Stern report (Stern, 2007) where the costs of the changes identified by the ONU international panel on the climate change (IPCC, 2007) are quantified. One of the foreseen changes is the increase of drought periods, changes described as "*existence of a high level of confidence in the fact that hydric resources will be reduced due to the climate change in some regions (Mediterranean Basin…)*" (IPCC, 2007, p. 8).

The studies that have evaluated the impact of the climate change on agriculture can be grouped in two categories: on one side, the general computable equilibrium models (CGE) (i.e., Quiroga and Iglesias, 2007) and on the other the micro-economic models at farm level with partial equilibrium (Pérez Domínguez and Holm-Müller, 2005). In both types of models, the behaviour of the different agents faced to changes in the distribution or the quantity of different climate events is simulated. Additionally, in the case of CGE models, hypothesis must be done on the development of other aspects such as economic and population growth. A common characteristic of these analyses is that they are directed towards the future, the present work looks into the past instead. The approach proposed here less is complex from a modelling point of view, perhaps less ambitious, but more transparent and understandable for policy makers. Considering climate change is already taking place, at least as far as droughts are concerned, its economic impact can be evaluated based on actual changes and, therefore, if the probability of certain events is known or a good estimate available, their economic impacts can be obtained from actual data. Likewise, if there would some information on different drought periods, it would be possible to model the intensity of the impact according to the shock's intensity. These tasks represent future lines of research that would complete the analysis of the climatic change impact using the input-output frame and would complement the studies based on CGE or partial equilibrium models.

Therefore, if climate change in the future will result in that drought periods will increase, these can be evaluated in similar terms to the one reported. The stability of the results is kept whenever the productive structure of the analysed area is kept constant, a hypothesis that can be consider similar to the technological limitations in the micro-economic models. Of course other effects of climate change, such as raise in temperatures, would have additional effects, but could also be considered in the proposed framework.

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