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Economic Regional Impacts of Water Transfers: the Role of Factor Mobility in a Case Study of the Agricultural Sector in the Balearic Islands

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SUMMARY: Using a CGE model for the Balearic Islands, we simulate the effects of an agricultural water market in the farming sector facing reductions in the water endowment. The market lessens the negative effects on farming communities of short-term water restrictions associated with cyclical droughts. However, in scenarios of permanent reductions, such as those envisaged by global warming predictions or those that result from the implementation of the European Water Framework Directive, a water market may aggravate the negative effects of water shortage. Therefore, the paper shows that generalizations cannot be made about the effects of water markets on farming communities.

KEYWORDS: Rural communities, applied general equilibrium, water markets.

JEL classification: D58, Q1, Q25, R13.

Efectos económicos regionales de las transferencias de agua: el papel de la mobilidad de los factores en el caso del sector agrícola de Baleares

RESUMEN: Mediante un modelo CGE para Baleares simulamos los efectos de un mercado de agua en la agricultura ante escenarios de reducción en la dotación de agua. Los resultados muestran como dicho mercado ayudaría a mitigar los efectos negativos que producen las sequías cíclicas sobre las comunidades agrícolas, mientras que podría agravar los efectos negativos de una reducción permanente en la disponibilidad del agua causada, por ejemplo, por el cambio climático o la aplicación de la Directiva Marco del Agua. Ello pone de manifiesto que no es posible realizar generalizaciones acerca de los efectos regionales de un mercado de agua.

PALABRAS CLAVE: Comunidades agrícolas, equilibrio general aplicado, mercados de agua.

Clasificación JEL: D58, Q1, Q25, R13.

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1. Introduction

Due to the growing interest in finding a balance between the environmental quality of water systems and the need to cover human needs, managing the demand for water has taken a prevalent position within water policies recommended or mandated by leading international bodies (the OECD, International Water Supply Association, European Union and World Bank). Basically, emphasis is being placed on the conservation, recycling and more efficient use and allocation of water. The idea is to manage the demand for all uses in a more efficient way in order to encourage water savings so that "new" supplies are made available and water can be more efficiently allocated to different uses and users.

In the specific case of the European Union, the Water Framework Directive (2000) points to the need to introduce water conservation policies, reducing the pressure of economic activities in order to improve the condition of our water-based ecosystems. To accomplish this, it recommends the use of economic instruments and the implementation of water pricing policies that recover all the costs of the water service.

In Spain, a few initiatives have been made to apply the Water Framework Directive (WFD) through a series of Activities for the Management and Use of Water (A.G.U.A in Spanish)[1], designed to guarantee the availability and quality of water throughout the whole country. Among the specific initiatives that it contemplates, it is worth highlighting the creation of Water Banks in all river basins so that water rights can be reallocated based on the criteria of equity, efficiency and sustainability. The aim is to reduce water deficits in certain river basins and to ensure a good water status for Spanish surface waters and ground waters.

Within the current guidelines of hydrological policies, emphasis has been placed on the benefits of allocative efficiency through institutional changes that permit the introduction of water transactions. Nonetheless, arguments have also been put forward against the introduction of water markets, many highlighting the possible negative effects for farming communities [Howitt (1994), Schmidt and Plaut (1995)]. These arguments state that the introduction of water markets would lead to a reduction in these communities' agricultural output since it would encourage farmers to sell their water allowance, with big impacts on third parties engaged in other rural activities. These sales could affect sectors like livestock farming, agricultural inputs industries, and the processing of agricultural products, leading to a reduction in the taxable base and, by extension, to a drop in the quality of public services and/or to a selective process of migration so that public facilities would be under-used [see Nunn and Ingram (1988) for a case study that confirms these effects].

Academic studies that attempt to test the existence of regional effects provide contrasting results. Some studies confirm the existence of significant negative effects on farming communities. For example, Seung *et al.* (2000) combine a dynamic computable general equilibrium model (CGE) with a recreation demand model to show

[1] Approved by the Ministry of the Environment in June 2004 and available at http://www.mma.es/secciones/agua/entrada.htm.

that reallocating the water used for agriculture to recreation in Churchill County (Nevada) would have negative effects on agricultural output and employment. Meanwhile, Zekri and Easter (2005) apply a linear programming model to Tunisia and show the negative effects of a water market on employment and farmers' spending on inputs and machinery.

Other studies obtain results that minimize the secondary regional effects. For instance Saliba (1987) demonstrates the low incidence of social problems in river basins where markets have been operating for some time, like the Colorado River. Also focusing on this river basin, a study by Howe *et al.* (1990) about the impact of the sale of water rights involving agricultural to urban transfers leads to the same conclusion. Nunn and Ingram (1988) come to a similar opinion, also highlighting that if the income that is obtained by those selling water is reinvested in the exporter area, it is very likely that secondary benefits can be reaped that are at least equal to those that have been lost. Another additional case is a study by Arriaza *et al.* (2002), which uses a multi-criteria programming model to show that while it is true that a water market in the Guadalquivir basin (Spain) might have positive regional effects, they would not be very significant.

At the same time, some studies show that transferring water rights would have significant positive effects. This is the case of the simulation model developed by Vaux and Howitt (1984) for California, where a net increase in wealth was forecast both for the agricultural sector and other sectors. Using a microeconomic production model, Dinar and Letey (1991) show that, for the same State, transferring some agricultural water rights to the urban sector would generate a rise in agricultural income and a reduction in the contamination of aquifers. Meanwhile, the results of a simulation model of water transfers in the Maipo river basin in Chile by Rosegrant *et al.* (2000) show an increase in the net benefits of the agricultural sector of up to 20%. In this same country, Hearne and Easter (1995) estimate the economic gains of a market with intersectorial and intrasectorial transfers between farmers in the Elqui and Limarí valleys.

If water that is used for low-value crops (fodder and grass) is transferred, the benefits of a water market for the agricultural sector can be higher, as demonstrated by Rosegrant *et al.* (1995) for the Tamil Nadu basin (India) and by Vergara (1996) for the Chilean case. Furthermore, water transfers might have a positive effect in agricultural employment as shown by Calatrava and Garrido (2001) using a non-linear mathematical programming model to simulate a water market in the Guadalquivir basin (Spain). In the same line, using a multi-criteria programming model applied to the Duero Valley (Spain), Martínez and Gómez-Limón (2004) show how water transfers can reduce the negative effect of droughts on agricultural employment by between 20% and 45%.

Lastly, other studies detect positive effects, using a general equilibrium analysis. For instance, Diao and Roe (2000) show how an agricultural water market can have long-term positive effects on land rents and agricultural wages. In a somewhat different context, Diao *et al.* (2005) show how water transfers lead to an increase in agricultural production and income, despite the drop in agricultural wages. Similarly, Roe *et al.* (2005) use a computable general equilibrium model to show that reallocating water among farmers leads to significant increases in farmers' output and benefits.

Given the water exchanges that might potentially result from the implementation of the A.G.U.A. programme and the WFD in Spain, and given the diversity of results that have been obtained on the regional effects of water markets, new applied research must be conducted in order to forecast these effects. The aim of this study is to provide reasons that account for the differing effects of water markets on farming communities, aside from differences in the target areas under analysis. More specifically, we demonstrate the dependency of these effects on the degree of intersectorial factor mobility[2]. With this purpose in mind, we use the Computable General Equilibrium Model for the Balearic Islands already used in Gómez *et al.* (2004), and in Tirado *et al.* (2006). In Gómez *et al.* (2004), a variation of this model is used to investigate the effects of an agricultural-urban water market. In Tirado *et al.* (2006) the effects of a water market exclusively among Balearic farmers are simulated. In this last study, we simulate and compare the effects of a reduction in the water endowment in a situation in which water is allocated by the authorities and in another scenario in which water transfers are allowed, but only between agricultural uses. The analysis is carried out under the assumption of limited factor mobility. The present paper extends the analysis in Tirado *et al.* (2006) focusing on the effects of an agricultural water market on farming communities facing different draught scenarios. Specifically, the main contribution of this paper is to compare results under different assumptions about factor mobility, and in this way to show the relevance of these assumptions for the results obtained regarding the effects of the water market on farming communities.

Thus our analysis considers reductions in water endowments that take place in two different contexts, one with a low level of factor mobility [as in Tirado *et al.* (2006)] and the other with high mobility. In the first context, reductions in water endowments could be equated with droughts originated by below-average precipitation periods, which, as the next section shows, are very common in the Balearic Islands' climate. In the second scenario the fall in available water could be interpreted as a reduction in water quotas, possibly as a result of the implementation of the new policy guidelines that stem from the WFD, or as a fall in the natural endowment brought about by global warming. Our contribution is not only to consider new assumptions regarding factor mobility, but specially to compare both scenarios. This is why, just when it is strictly necessary for comparison, some of the results in Tirado *et al.* (2006) are reproduced in this paper.

In general terms, the model shows that an agricultural water market is a favourable institutional framework for farming communities that face cyclical droughts. However, in a context of permanent reductions in the water endowment, a water market reduces agricultural employment, and it would only improve agricultural income in contexts of very severe water shortfalls.

[2] Using a CGE model, Seung *et al.* (1998) analyze the effects of a water market in the Walker river basin (USA) under different hypotheses of interstate (not intersectorial) factor mobility.

The rest of the study is structured as follows. In next section, the hydrological characteristics of the area under study are described. In section three, a description is made of the theoretical model. Section four describes the empirical application and calibration of the model. In section five we present the simulation results. These assess the implications of an agricultural water market in eleven different scenarios where there is a reduction in the water endowment for agricultural use. More particularly, we show the effects on water transfers, on the production of different crops and on agricultural income and employment. Finally, the closing section presents the main conclusions of the study.

2. The hydrological situation in the Balearic Islands

Water scarcity in the Balearic Islands is due to a combination of several different factors that justify a search for efficient water management tools. Underground water is the main natural source of raw water. Given the archipelago's topographical and geological characteristics, there are no permanent rivers or natural sources of surface water, while reservoirs represent only a small fraction of the total water supply. Moreover, due to the Mediterranean climate, the availability of water is dependent on very irregular rainfall and, during dry hydrological years, reserves may fall to half those of an average year. Seasonal rainfall and the islands' economic specialization in sun and sand tourism are two additional important reasons why water is a problematic issue for the Balearic economy, since 65% of the archipelago's rainfall is concentrated over the winter months whereas the demand for water is highest in summer, the dry season.

The current scarcity could worsen in the future due to the threat of global warming. Most studies forecast that global warming will have a negative impact on the availability of water in the Mediterranean as a result of higher temperatures and a drop in rainfall [see Eisenreich (2005)]. For instance, the Ministry of the Environment's forecast for 2030 is a reduction in the Balearic Islands' average share of fresh water that ranges from 5% to 12% [see Moreno (2005)]. Higher evapotranspiration due to warmer weather and lower runoff in Southern Europe [see European Environmental Agency (2006)] will reduce the aquifers capacity for replenishment. For many over-exploited aquifers in the Balearic Islands, this lower capacity for replenishment may have a negative effect on the quality of water. This secondary effect would further limit the usable water available for human consumption. As global warming is the result of cumulative effects, its potential repercussions on the availability of water in the Balearic Islands will span a long period of time, so they can be treated as a permanent shock.

3. A general equilibrium model applied to the Balearic Islands

As in Tirado *et al.* (2006), the model distinguishes sixteen agricultural sectors (see Table 1) and seven productive non-agricultural sectors: energy, industry, building, tourism, services, production and distribution of drinking water and, finally, a last sector that covers the primary sector except for agriculture.

TABLE 1

Hectares by crops and irrigation technology (sectors) and water consumption by irrigated sectors

Crops	**Rainfed Area** (Hectares)	**Irrigated Area** (Hectares)	**Gross Consumption** (Hm^3)
Cereals	Sector 1 31.934	Sector 2 2.240	7,623
Pulses	Sector 3 2.087	Sector 4 28	0,064
Tubercules	–	Sector 5 2.930	25,972
Fodder	Sector 6 8.302	Sector 7 4.029	34,69
Green vegetables	Sector 8 296	Sector 9 6.308	51,959
Citrics	-	Sector 10 3.224	23,587
Fruits	Sector 11 68.507	Sector 12 2.531	16,867
Industrial crops	Sector 13 9	Sector 14 268	1,651
Flowers	–	Sector 15 211	0,904
Other nonirrigated crops	Sector 16 24.579	-	
TOTAL	135.714	21.796	163,317

Source: Elaborated from data of the Plan Nacional del Regadío, M.A.P.A. (2001) and data provided by the Balearic Government.

Our assumptions about economic agents, external trade, production factors and production technologies are the same as in Tirado *et al.* (2006)[3], except for new assumptions regarding factor mobility, that are explained in the following paragraphs.

We consider water supply as use-specific, that is, farmers and water supply and distribution companies have exclusive rights that allow them to make use of a certain volume of underground water for a legally specified use, with no exchanged uses being allowed. However, in the specific case of water for the agricultural use we will consider two scenarios. First, in the non-market scenario water is specifically allocated to each type of irrigated crop and so it can only be used by the said sector. Second, in the market scenario, water is not specifically allocated to certain crops, and water transfers between different irrigated crop sectors are allowed[4].

[3] We refer to this paper and to Gómez *et al.* (2004) for a detailed explanation of these assumptions.

[4] If we allow water transfers between agricultural and other uses, as it is done in Gómez *et al.* (2004), water transfers from agricultural to urban uses would dominate water transfers between agricultural sectors, since it is in the urban use where water has its highest value.

It is widely known in the literature on general equilibrium models that results are largely dependent on the level of factor mobility. It is also common in this type of literature to associate the level of mobility with the time horizon under analysis and the permanent or transitory nature of the shocks that are being simulated. Thus a lower level of mobility is associated with short-term scenarios and an analysis of transitory shocks, while the assumption that factors like capital or land are intersectorally mobile serves to simulate responses to permanent changes over a longer time horizon.

Bearing this in mind, we developed two variations of the model which differ with regard to the mobility of land and agricultural capital. Thus in model 1 *(M1),* both capital and land are assumed to be crop-specific, fixed factors. However, mobility of these factors is allowed between irrigated and non-irrigated techniques. This model coincides with the one employed in Tirado *et al.* (2006) and allows for the simulation of a short-term analysis, where, when there is a temporary drought, the farmer must decide whether to continue using all the available water or whether to sell all or part of his allowance, in which case she can choose to grow non-irrigated crops. However, the farmer does not have enough time to change his production plans from one crop to another, since in many cases they are decided before knowing the climatic conditions for that year, or to reallocate specific factors (land and capital), and she can only alter production by changing the single variable factor, labour. With model 2 *(M2)*, in contrast, land and capital are fully mobile, both between crops and between irrigated and non-irrigated techniques. This assumption is more appropriate to explore the effects of permanent reductions in the water endowment for agricultural use, whether due to climatic reasons or institutional restrictions.

4. Empirical application and calibration

As it is explained in Tirado *et al.* (2006), the model is developed using information from the input-output tables for the Balearic Islands. The final output value of each crop is calculated using data from the National Agricultural Accounting Network for 1997 (MAPA, 1999) and from data supplied by the Government of the Balearic Islands' Department of Agriculture for the same year.

It is assumed that the sum of the items "Wages and Earnings" and "Social Security Contributions" in the input-output tables constitute labour income. The value of income from land is calculated using data supplied by the Balearic Department of Agriculture and the yearly survey on land prices for 1997. Investment income is calculated as the difference between the gross value added at factor cost and income from labour and land. For the purposes of simplification, we consider consumption by non-residents to be exports. It is also assumed that public or joint consumption forms part of the consumption of the representative agent.

The data for the different water endowments is mainly taken from the Balearic Hydrological Plan (Govern de les Illes Balears, 1999). The water endowment for urban use amounts to 109 hm^3. This includes the amount of underground water and water reservoirs used by the water supply sector, plus the water used by the industry not connected to the public water network and golf fields' irrigation. Table 1 shows gross water consumption per crop in 1997. This is calculated using data on the surface area of crops supplied by the Balearic Department of Agriculture and Fisheries and information on net consumption per crop from the National Irrigation Plan (MAPA, 2001). We further assume a return flow of 22%. As can be seen, the total water endowment for agricultural use amounts to 163, 317 hm^3.

The model is calibrated using the Mathematical Programming System for General Equilibrium (MPSGE), a subsystem of the General Algebraic Modelling System (GAMS, 2001). The elasticities of substitution and transformation are those already used in Tirado *et al.* (2006).

The price of labour is set as the numeraire. As to the rest of prices, we follow the traditional Harberger Convention and set prices equal to one for the reference scenario to transform monetary values in the I-O table into physical units[5]. Nevertheless, we do not apply this normalization to the following cases.

First, the existence of indirect taxes on production implies a difference between the buyer and the seller prices. We opt to normalize the buyer's price to one and, therefore, the producer's price is different to one.

Second, in the production of drinking water the amount of output (drinking water) must be equal to the amount of input (raw water). This makes necessary to calibrate the drinking water price in order to obtain a unitary Leontief.

Third, the absence of an existing water market for agricultural use in the reference scenario means that a reference price equal to zero is set. This is due to the fact that the farmer is endowed with a right to make use of a certain volume of underground water. Once the farmer has this right, she does not have to pay any price for the drawn water except for the extraction costs.

The database refers to a year, 1997, when no water transfers were allowed and where the available water was allocated for each use/user by the authorities. As explained in Tirado (2003), year 1997 can be considered a year with normal rainfall, with available resources of about 95%. This dataset is used to calibrate the model, which implies the assumption that the situation in 1997 was an equilibrium of the model. This is why, in the baseline scenario (*SB* in the tables), the water market has no effect on the considered variables and changes in the water endowment are needed for the water market to have any noticeable effect.

5. Analysis of the results

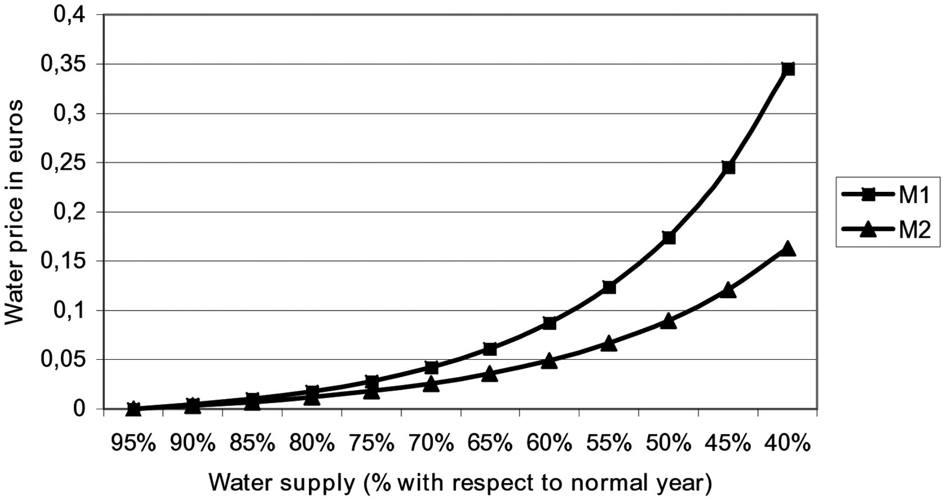
In both water market and non-market scenarios we simulate eleven different drought scenarios in which there is a reduction in the available water, with a sequential 5% reduction in each case. These simulations are implemented in M1 and M2, that is, under the assumptions of temporary or permanent droughts, respectively. We therefore obtain four results for each drought scenario (no-market and temporary draught; market and temporary draught; no-market and permanent drought; market and permanent draught). In total, we implement forty-four simulations.

[5] Of course, prices are allowed to change in the different departures from the reference scenario.

In the analysis of results, we first consider the direction and volume of water transfers resulting from the water market. As explained before, water allocation in the *SB* is by assumption an equilibrium and, therefore, in the *SB* there are no water transactions. However, when allowed, water transactions take place in drought scenarios since the fall in water endowments increases water scarcity and the shadow price of water. However, this does not happen evenly among water uses. Therefore, farmers make profits from the Pareto improvements result from water transactions between different crops. As for the total volume that is transferred (see Table 2), it should be noted that a greater mobility of land and agricultural capital generates an increase in the total amount that is exchanged for each level of available water. Thus, if we allow land and capital, which are crop specific in M1, to become totally mobile, as in M2, water transfers rise between 61% and 74%, depending on the severity of the water restrictions. This higher volume of transactions is attributable to the fact that in M2 farmers have more potential for switching their production plans from one crop to another and reallocating factors in response to the drop in available water. Another way to put it is that, when there are specific factors, marginal product of water respond quickly to changes in the amount of water used. This response is slower with mobile factors, as it is possible to change quantities of more inputs jointly with changes in the water used. This greater flexibility would also explain the lower market price of water in M2: In Figure 1, we can see how, whereas water price increases in both models as water becomes less available, this increase is lower in M2.

FIGURE 1

Market price of agricultural water for different short and long run droughts



Source: Own calculations.

TABLE 2

Water endowment by crops (hm^3), water transfers by crops (hm^3), difference in water transfers between M2 and M1 (relative to initial endowment by crops, in percentage terms) and total water transfers (hm^3) under different factor mobility scenarios

	SB	**Water Supply (% of a normal hydrological year)**										
	95%	*90%*	*85%*	*80%*	*75%*	*70%*	*65%*	*60%*	*55%*	*50%*	*45%*	*40%*
Cereals												
Water Endowments	7,62	7,24	6,86	6,48	6,10	5,72	5,34	4,95	4,57	4,19	3,81	3,43
Water Transfers M1	0,00	–0,25	–0,50	–0,75	–0,98	–1,20	–1,41	–1,60	–1,76	–1,88	–1,95	–1,97
Water Transfers M2	0,00	–0,11	–0,23	–0,35	–0,48	–0,61	–0,74	–0,86	–0,98	–1,09	–1,18	–1,24
% Variation Water Transfers	0,00	1,96	3,99	6,07	8,21	10,39	12,61	14,83	16,96	18,88	20,41	21,38
Fodder												
Water Endowments	34,69	32,96	31,22	29,49	27,75	26,02	24,28	22,55	20,81	19,08	17,35	15,61
Water Transfers M1	0,00	–0,83	–1,63	–2,41	–3,16	–3,88	–4,58	–5,24	–5,85	–6,40	–6,87	–7,20
Water Transfers M2	0,00	–0,28	–0,59	–0,93	–1,29	–1,69	–2,11	–2,56	–3,02	–3,50	–3,98	–4,43
% Variation Water Transfers	0,00	1,66	3,33	5,03	6,73	8,44	10,16	11,89	13,60	15,22	16,64	17,70
Industrial crops												
Water Endowments	1,65	1,57	1,49	1,40	1,32	1,24	1,16	1,07	0,99	0,91	0,83	0,74
Water Transfers M1	0,00	–0,03	–0,07	–0,10	–0,13	–0,16	–0,18	–0,21	–0,24	–0,26	–0,29	–0,32
Water Transfers M2	0,00	–0,02	–0,03	–0,05	–0,07	–0,09	–0,12	–0,14	–0,17	–0,19	–0,22	–0,25
% Variation Water Transfers	0,00	1,19	2,33	3,40	4,37	5,23	5,97	6,58	7,09	7,54	8,08	9,01
Pulses												
Water Endowments	0,06	0,06	0,06	0,05	0,05	0,05	0,04	0,04	0,04	0,04	0,03	0,03
Water Transfers M1	0,00	0,00	0,00	0,00	–0,01	–0,01	–0,01	–0,01	–0,01	–0,01	–0,01	–0,01
Water Transfers M2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
% Variation Water Transfers	0,00	2,82	5,84	9,08	12,57	16,37	20,50	25,03	29,97	35,33	41,06	47,13
Tubercules												
Water Endowments	25,97	24,67	23,37	22,08	20,78	19,48	18,18	16,88	15,58	14,28	12,99	11,69
Water Transfers M1	0,00	–0,48	–0,93	–1,36	–1,75	–2,12	–2,46	–2,77	–3,06	–3,33	–3,60	–3,88
Water Transfers M2	0,00	–2,48	–4,72	–6,69	–8,34	–9,66	–10,61	–11,21	–11,47	–11,40	–11,04	–10,42
% Variation Water Transfers	0,00	–8,09	–16,20	–24,15	–31,72	–38,69	–44,86	–50,01	–53,96	–56,48	–57,29	–55,92
Fruits												
Water Endowments	16,87	16,02	15,18	14,34	13,49	12,65	11,81	10,96	10,12	9,28	8,43	7,59
Water Transfers M1	0,00	0,00	–0,01	–0,04	–0,09	–0,16	–0,26	–0,39	–0,54	–0,71	–0,90	–1,08
Water Transfers M2	0,00	0,53	1,08	1,63	2,20	2,78	3,39	4,02	4,67	5,33	5,99	6,62
% Variation Water Transfers	0,00	3,31	7,15	11,64	16,95	23,30	30,94	40,22	51,49	65,17	81,67	101,45
Green vegetables												
Water Endowments	51,96	49,36	46,76	44,17	41,57	38,97	36,37	33,77	31,18	28,58	25,98	23,38
Water Transfers M1	0,00	1,44	2,86	4,24	5,58	6,89	8,16	9,38	10,55	11,67	12,71	13,66
Water Transfers M2	0,00	2,08	4,15	6,18	8,17	10,09	11,92	13,60	15,04	16,14	16,73	16,66
% Variation Water Transfers	0,00	1,30	2,76	4,39	6,22	8,22	10,34	12,49	14,41	15,66	15,48	12,81

(cont.)

TABLE 2 *(cont.)*

	SB	Water Supply (% of a normal hydrological year)										
	95%	*90%*	*85%*	*80%*	*75%*	*70%*	*65%*	*60%*	*55%*	*50%*	*45%*	*40%*
Flowers												
Water Endowments	0,90	0,86	0,81	0,77	0,72	0,68	0,63	0,59	0,54	0,50	0,45	0,41
Water Transfers M1	0,00	0,02	0,05	0,07	0,09	0,11	0,12	0,13	0,14	0,14	0,11	0,05
Water Transfers M2	0,00	0,03	0,05	0,08	0,10	0,12	0,13	0,14	0,15	0,14	0,13	0,10
% Variation Water Transfers	0,00	0,55	1,07	1,52	1,85	2,00	1,91	1,54	0,96	0,66	2,57	11,83
Citrics												
Water Endowments	23,59	22,41	21,23	20,05	18,87	17,69	16,51	15,33	14,15	12,97	11,79	10,61
Water Transfers M1	0,00	0,12	0,24	0,35	0,45	0,54	0,63	0,70	0,76	0,79	0,79	0,74
Water Transfers M2	0,00	0,24	0,29	0,13	–0,28	–0,95	–1,86	–2,99	–4,23	–5,44	–6,43	–7,05
% Variation Water Transfers	0,00	0,51	0,25	–1,09	–3,85	–8,41	–15,08	–24,07	–35,24	–48,03	–61,27	–73,35
Total Water Transfers M1	0,00	1,59	3,14	4,65	6,12	7,54	8,90	10,21	11,45	12,59	13,62	14,46
Total Water Transfers M2	0,00	2,65	5,28	7,89	10,46	12,99	15,44	17,76	19,86	21,61	22,85	23,39

Source: Own calculations.

Table 2 reveals that, regardless of the level of factor mobility, most transfers are made for the cultivation of green vegetables, the crop with the highest shadow price. This result is coherent with those obtained in other studies in Spain and elsewhere [for instance, Vergara (1996), Rosegrant *et al.* (1995), Calatrava and Garrido (2001), Arriaza *et al.* (2002) and Diao *et al.* (2005)]. Flowers constitute another crop for which water would be bought in the market, irrespective of the degree of factor mobility. On the other side, farmers growing cereals, fodder, industrial crops and tubercules would become water sellers irrespective of the considered scenario.

However, the different assumptions regarding factor mobility also make some difference in the pattern of water transactions[6]. Thus greater mobility is beneficial for fruit crops (from which water would be sold in M1 but purchased it in M2) to the detriment of citrus plants (for which water would be purchased in all scenarios in M1, but sold in large amounts in M2). As for water sellers as growers of grain, fodder, industrial crops and tubercles, while different assumptions about factor mobility do not modify the sign of the transaction, they do have a significant impact on the volume. In fact, higher factor mobility implies lower amounts of water sold by the first three, whereas growers of tubercules sell more water and become the main seller in ab-

[6] Differences in water transactions between M1 and M2 are displayed in line "%variation water transfers" of Table 2, which measures, for each crop, the difference between water transactions in M2 minus water transactions in M1 over the water endowment resulting from the corresponding draught conditions.

solute terms. Finally, growers of green vegetables and flowers buy water in both scenarios, but higher factor mobility tends to increase their water purchases.

TABLE 3

Changes of agricultural sectorial output resulting from a water market creation in different short run draughts (in percentage terms)

M1		Water Supply (% of a normal hydrological year)											
		SB											
		95%	*90%*	*85%*	*80%*	*75%*	*70%*	*65%*	*60%*	*55%*	*50%*	*45%*	*40%*
Irrigated agriculture	Cereals	05	–0,98	–2,27	–3,95	–6,12	–8,89	–12,37	–16,66	–21,82	–27,84	–34,56	–41,68
	Industrial crops	0	–0,28	–0,67	–1,21	–1,96	–3,00	–4,45	–6,49	–9,37	–13,48	–19,37	–27,73
	Fodder	0	–0,54	–1,27	–2,26	–3,58	–5,36	–7,71	–10,81	–14,84	–19,98	–26,33	–33,81
	Pulses	0	–0,43	–1,01	–1,77	–2,77	–4,07	–5,73	–7,85	–10,48	–13,67	–17,42	–21,60
	Fruits	0	0,00	–0,01	–0,07	–0,19	–0,41	–0,82	–1,49	–2,55	–4,15	–6,42	–9,40
	Green vegetables	0	0,08	0,24	0,53	1,06	2,04	3,77	6,68	11,27	17,89	26,71	37,84
	Tubercules	0	–0,11	–0,26	–0,46	–0,75	–1,15	–1,70	–2,49	–3,63	–5,28	–7,77	–11,64
	Citrics	0	0,02	0,04	0,08	0,14	0,23	0,36	0,54	0,81	1,18	1,67	2,22
	Flowers	0	0,24	0,67	1,40	2,57	4,35	6,84	10,00	13,56	16,77	17,47	10,27
Rainfed agriculture	Cereals	0	–0,01	–0,04	–0,10	–0,19	–0,34	–0,57	–0,94	–1,49	–2,30	–3,42	–4,90
	Industrial crops	0	0,18	0,42	0,74	1,17	1,74	2,50	3,48	4,72	6,21	7,76	8,66
	Fodder	0	0,22	0,51	0,89	1,40	2,06	2,91	4,00	5,35	6,95	8,73	10,43
	Pulses	0	0,00	0,00	0,00	0,00	–0,01	–0,01	–0,02	–0,04	–0,06	–0,09	–0,13
	Fruits	0	0,00	0,00	0,01	0,02	0,05	0,09	0,15	0,25	0,37	0,53	0,69
	Green vegetables	0	–0,08	–0,24	–0,51	–0,97	–1,71	–2,71	–3,68	–3,88	–2,26	1,97	9,18
	Others	0	0,00	0,00	0,00	0,00	0,00	–0,01	–0,01	–0,02	–0,03	–0,04	–0,05

Source: Own calculations.

A second analysis refers to the effects of the water market creation on sectorial agricultural output, which is shown in Tables 3 and 4. When comparing Tables 3 and 4 with Table 2, we can see that the effects of the market on irrigated agricultural output have a high correlation with water transfers. Thus, as a general rule, when farmers growing one crop sell (buy) water, their output fall (increase). Furthermore, when changes in factor mobility induce a change in the pattern of water transfers, it also has a similar effect on the consequences of the water market on irrigated agricultural output. To put two examples, higher factor mobility not only implies higher water sales by growers of tubercules, but also tends to exacerbate the negative effect of the market on tubercules production; it also implies larger water purchases for irrigated

TABLE 4

Changes of agricultural sectorial output resulting from a water market creation in different long run draughts (in percentage terms)

M2		Water Supply (% of a normal hydrological year)											
		SB											
		95%	*90%*	*85%*	*80%*	*75%*	*70%*	*65%*	*60%*	*55%*	*50%*	*45%*	*40%*
Irrigated agriculture	Cereals	0	–0,72	–1,72	–3,07	–4,81	–6,98	–9,62	–12,72	–16,32	–20,41	–24,99	–30,00
	Industrial crops	0	–0,52	–1,26	–2,28	–3,64	–5,39	–7,62	–10,38	–13,79	–18,01	–23,20	–29,53
	Fodder	0	–0,45	–1,13	–2,09	–3,38	–5,06	–7,16	–9,72	–12,82	–16,55	–21,03	–26,33
	Pulses	0	–0,07	–0,28	–0,63	–1,12	–1,72	–2,35	–2,91	–3,24	–3,21	–2,69	–1,51
	Fruits	0	0,37	0,80	1,45	2,59	4,50	7,52	11,98	18,23	26,62	37,55	51,54
	Green vegetables	0	1,46	3,48	6,15	9,56	13,78	18,86	24,82	31,61	39,01	46,63	53,76
	Tubercules	0	–6,62	–13,87	–21,61	–29,67	–37,82	–45,86	–53,61	–60,93	–67,72	–73,89	–79,32
	Citrics	0	0,16	–0,31	–1,56	–3,75	–7,06	–11,66	–17,76	–25,44	–34,63	–44,90	–55,45
	Flowers	0	1,22	2,73	4,53	6,61	8,94	11,45	14,02	16,45	18,37	19,26	18,41
Rainfed agriculture	Cereals	0	–0,35	–0,92	–1,77	–2,95	–4,49	–6,42	–8,73	–11,41	–14,44	–17,79	–21,39
	Industrial crops	0	–0,28	–0,72	–1,38	–2,29	–3,53	–5,15	–7,21	–9,80	–13,05	–17,12	–22,19
	Fodder	0	–0,20	–0,57	–1,17	–2,06	–3,27	–4,85	–6,82	–9,22	–12,09	–15,49	–19,51
	Pulses	0	–0,13	–0,44	–1,01	–1,86	–3,04	–4,53	–6,31	–8,31	–10,45	–12,64	–14,78
	Fruits	0	–0,24	–0,80	–1,66	–2,77	–4,00	–5,22	–6,28	–7,02	–7,26	–6,82	–5,49
	Green vegetables	0	1,39	3,26	5,70	8,76	12,50	16,94	22,06	27,79	33,91	40,01	45,48
	Others	0	0,02	–0,11	–0,40	–0,92	–1,66	–2,65	–3,84	–5,20	–6,67	–8,18	–9,67

Source: Own calculations.

green vegetables which in turn boosts the market-induced increase in their output. Another interesting case is the fruit sector. This sector is classified by the literature among those where water use reaches its highest value. Despite this, in M1 the market induces fruits to sell water and reduce production. This can be explained by the difficulty of woody crops to adapt their production plans to short run shocks. This is confirmed by the different behaviour in M2: when factor mobility is high enough, the response of fruit producers to the water market is to buy water and increase the output.

By definition, rainfed agriculture does not make use of water and, therefore, water transfers have no direct effect on these crops. Nevertheless, as shown in Tables 3 and 4, the creation of a water market modifies rainfed production through an effect on intersectorial transfers of other production factors different from water. Moreover, the comparison on Tables 3 and 4 reveal that the effects are different depending on whether the economy is hit by either short or long run droughts. Thus, in the first case (Table 3), the water market has a mild effect on rainfed production. Moreover, there is not a dominant direction of change, with some crops increasing their production and some others reducing it. However, in the context of a long run drought (Table 4), production of rainfed crops is strongly affected by the water market creation, which causes an almost generalized fall in production. The only exception is green vegetables, which turn out to be one of the rainfed crops with higher added value [Calatrava and Garrido (2001), Martínez and Gómez-Limón (2004)].

A corollary of the analysis in the two preceding paragraphs is that the capacity of the water market to stimulate the reallocation of resources to those crops with highest added value very much depends on the considered time horizon or, put in a different way, on the mobility of other production factors. Thus, as explained before, in our long run scenarios, the water market clearly favours crops like fruits and green vegetables over the rest of crops, something that happens to much lesser extent in the short run scenario.

Third, as to the welfare effects of the water market, the Hicksian equivalent variation of the representative agent indicates that the water market improves the welfare of the representative Balearic agent in all scenarios, something that should be attributable to the positive effect on resource allocation efficiency. This indicator shows an improvement in aggregate Balearic welfare, but our primary focus is on the regional effects on agricultural areas. Since we do not have sufficient data to identify a representative agent for farming communities, the market effects on these communities are proxied by the behaviour of the agricultural gross value added (GVA) and employment. Although this is an indirect way of measuring the impact on welfare, it is also the common procedure used in literature.

TABLE 5

Changes of rural labour, agriculture's GVA and water rents from a water market creation in different short and long run draughts (in percentage terms)*

		Water Supply (% of a normal hydrological year)											
		SB											
		95%	*90%*	*85%*	*80%*	*75%*	*70%*	*65%*	*60%*	*55%*	*50%*	*45%*	*40%*
Rural Labour	M1	0	0,00	0,01	0,04	0,13	0,32	0,67	1,29	2,25	3,51	4,97	6,43
	M2	0	–0,25	–0,58	–0,96	–1,39	–1,84	–2,29	–2,67	–2,93	–2,99	–2,75	–2,09
GVA agriculture without water rents	M1	0	0,28	0,84	1,93	3,95	7,59	13,74	23,10	34,94	46,28	53,47	54,74
	M2	0	0,16	0,48	1,00	1,77	2,82	4,20	5,91	7,95	10,29	12,88	15,65
Water Rents	M1	0	–28,78	–35,36	–42,45	–49,55	–55,97	–60,88	–63,49	–63,16	–59,45	–52,15	–41,34
	M2	0	–42,53	–46,25	–49,40	–51,88	–53,66	–54,69	–54,93	–54,33	–52,79	–50,24	–46,64
GVA agriculture with water rents	M1	0	0,02	0,06	0,14	0,30	0,61	1,15	2,05	3,42	5,27	7,48	9,84
	M2	0	–0,18	–0,36	–0,54	–0,70	–0,82	–0,86	–0,80	–0,60	–0,19	0,50	1,53

Source: Own calculations.

* This data compares, for each drought scenario, the percentage change resulting from the water market creation. For instance, result in the upper-right cell is: (rural labor with $market_{40\%}$-rural labor without $market_{40\%}$)/rural labor without $market_{40\%}$, where the subindex refers to the drought severity.

In Table 5, changes in employment resulting from the water market creation are presented for models M1 and M2. In a short run scenario (M1), the market lessens the negative effect of droughts on jobs. On the contrary, in the context of long run water restrictions (M2), the water market exacerbates job losses in the agricultural sector. This latter result can be explained through a more detailed analysis by crops that reveals factor substitution in the fruit production. Thus, in the long run scenario, those crops that expand (contract) their production to a higher extent are also those that create (destroy) more jobs, with the outstanding exception of fruits. In the case of fruits, the water market both expands production and reduces this crop's employment, except when the market is created in a context of very severe water shortage, when the water-market-induced increase in fruit production is accompanied by a small increase in this crop's employment. But even in this latter case, the employment increase is much smaller, in percentage terms, than the increase in production and water used, revealing an intense factor substitution[7]. It may be the case that capital mobility in M2 allows fruit production to change to more efficient irrigation and production techniques that may be labour-saving.

Table 5 also presents the effect of the water market in two measures of agricultural GVA, one that excludes and other that includes water rents. Water rent of a crop is equal to the marginal value of water in this crop production times the amount of water used. This marginal value of water is a shadow price when there is no market whereas is equal to the market price when transactions are allowed. First, when water rents are not included, that is, when we consider the sum of capital, land and labour income[8], data reveals that in both short and long run scenarios the water market mitigates the fall in GVA associated with water shortages. Nevertheless, this happens to a lesser extend in the long run one, an effect that may be associated to the fall in employment in this scenario. Second, water rents are diminished by the water market in all scenarios, due to the fall in water price when the market is created which is more pronounced in the long run one (see figure 1). Finally, when total GVA is analyzed, the water market brings about a positive effect in total GVA when the economy faces short run droughts. However, in most of the long run droughts scenarios the fall in water rents associated to the water market dominates over the increase in other agricultural income sources, giving place to a negative effect on total GVA. Only in contexts of very severe water shortfalls a water market would improve total agricultural income, although to a much lesser extent than in the case of short run droughts of the same magnitude.

Thus it seems that as it becomes easier for farmers to reallocate specific factors between different crops, a water market intensifies the negative effects on agricultural income and employment due to reductions in the available water endowment. These results show how the regional effects of a water market are not just dependent on the characteristics of the geographical area under study, but also on the

[7] Data on employment changes in the fruit production is not presented in the paper, but is available on request.

[8] Capital, land and labour income are the respective market price times the amount of each factor used in production.

nature of the shocks that affect the availability of water and the adaptation time to these shocks.

6. Conclusions

The appeal of water markets, based on potential improvements in water allocation efficiency, should be weighed up against their possible redistributive effects, which might be detrimental to certain sectors of society. The literature has focused on the possible negative effects that water markets might have on communities and regions that are dependent on agriculture. However, the literature offers ambiguous conclusions about the impacts in the farm sector.

In order to assess the effects of water markets on the agricultural sector of the Balearic Islands, using a computable general equilibrium model, we have simulated the role of an agricultural water market in different scenarios where there is a reduction in the water endowment brought about by cyclical or permanent water shortages. Besides the usefulness of this analysis in contributing to better water management in the Balearic Islands, the results show, in consonance with literature, that no simple generalizations can be made about the effects of a water market on agricultural communities. Specifically, our study shows how sensitive those effects are on assumptions about factor mobility and, therefore, hints that the differences in modelling assumptions can be an important source of lack of consensus in the literature.

Thus, in our simulations, low factor mobility is assumed for scenarios of short-run droughts, whereas higher factor mobility is considered when representing the effects of permanent water shortfalls. We show that the potential positive effects that a market might have on the agricultural GVA and employment would be attributable to the existence of limits in the reallocation of factors, which is characteristic of a short term scenario. When there is sufficient factor mobility within the agricultural sector (that is, in a long-term scenario), a water market would lead to a fall in agricultural employment and, in most of the scenarios that were simulated, to a reduction in the agricultural GVA. Nevertheless, this latter result is determined by the reduction that the water market has on water rents which, in most of the long run scenarios, tends to compensate the increase in the rest of agricultural income triggered by the water market.

In the context of the Balearic Islands, these results can be interpreted in connection with specific climatic phenomena. According to this interpretation, an agricultural water market would help to mitigate the negative effects of cyclical (short term) droughts on farming communities, while it could worsen the negative effect of permanent reductions in the availability of water caused by global warming or by more restrictive policies as those resulting from the implementation of the European Water Framework Directive.

Nevertheless, certain limitations in the data and the methodology may affect the validity of our results. First, disaggregation of the Balearic agricultural sector in terms of agricultural areas, size of farms or crop composition is limited by the unavailability of good quality data at these levels of decomposition. Second, we model an ideal case of water market without transaction costs. To the extent that these transaction costs exist, water transfers triggered by the market will be lower than our simulations predict. Finally, the CES production functions imposed by the use of a CGE model may not be able to reflect adequately a common practice in a context of water scarcity, viz. regulated deficit irrigation.

7. List of Acronyms

CGE: Computable General Equilibrium.
GVA: Gross Value Added.
OECD: Organisation for Economic Co-Operation and Development.
WFD: Water Framework Directive.
AGUA: Actuaciones para la Gestión y Utilización del Agua.
USA: United States of America.
MAPA: Ministerio de Agricultura, Pesca y Alimentación.
GAMS: General Algebraic Modelling System.

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