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AUTHORS	M. Alejandro Cardenete Geoffrey J.D. Hewings

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M. Alejandro Cardenete (Spain), Geoffrey J.D. Hewings (USA)

Water price and water sectoral reallocation in Andalusia. A computable general equilibrium approach

Abstract

The objective of this paper is to analyze the effects that an increase in the price of water delivered to the agriculture sector to promote the conservation of this resource would have on the efficiency of the consumption and the possible reallocation of water to the remaining productive sectors. The analysis is motivated by the fact that agriculture consumes a disproportionately large amount of water at very low prices – subsidized. The methodology that is used to explore the implications on the economy is a computable general equilibrium model (CGE), previously designed for an analysis of the direct taxes of the Andalusian economy (Cardenete and Sancho, 2003), but now enhanced and extended to include emissions of pollutants and the introduction of environmental taxes (André, Cardenete and Velázquez, 2005). This model has been further modified to introduce the variations in the water price that the authors will try to analyze by means of a tariff applied on the production structure. The main conclusion drawn indicates that, although the tax policy applied does not correspond to a significant water saving in the above-mentioned sector, a reallocation of this resource is achieved which seems to generate a more efficient and more rational behavior from a production point of view.

Keywords: environmental tax reforms, computable general equilibrium, water price.
JEL Classification: C56, D58, H21, H22.

Introduction

The problem of water shortages in Andalusia in years of drought and the intense competition for this resource are well known. However, water consumption by the productive sectors in the region appears not to be rational because the Andalusian economy has an intensive water consumption production system (Velazquez, 2006) and in fact is a net exporter of products that require an intensive water use in their production process (Dietzenbacher and Velázquez, 2007). This phenomenon is due to many factors: the old water culture in the region, the system of prices and tariffs of the resource, the institutional system of concessions of water use and other aspects that frame the management system. It is impossible to analyze the impacts of all of them in a single paper. However, each component is important in building a complete picture of the role of water and water policy (especially conservation) in the future growth and development of the Andalusian economy.

The paper has two objectives. First, we analyze the possible effects that an increase in the agriculture water tariff[1] would have on the Andalusian economy and on water conservation. Secondly, we evaluate the water reallocation to other sectors of the economy generated by agriculture water price increases. There are two important reasons to focus on agriculture. In the first place, agriculture is one of the greatest water consuming sectors, absorbing more than 80% of the resources in the region; and, in the second place, the tariff paid for the water in this sector is very low (on the average, it is 0.01 €/m^3)[2]. At this point, it is important to clarify that we will not only simulate the existence of a water market in the agriculture sector but also an increase in the agricultural water tariff, fixed by the government.

In this paper, a regional computable general equilibrium (CGE) model is used to evaluate the environmental and economic effects of an agriculture water tariff on the Andalusian regional economy. We use an extension of the model developed by Cardenete and Sancho (2003), including polluting emissions and the environmental taxes that were added in André et al. (2005), but adapted to introduce variations in the price of water so that market forces are able to generate the possibility for water reallocation onto other sectors.

The paper is organized as follows. Beyond this introduction, Section 1 describes the state of the art in modeling this type of research and places the contribution in the context of the prevailing literature. In Section 2, the model is developed while in fourth Section 3 the results are analyzed. The paper concludes with some final remarks.

1. Background

Next, we will briefly review some relevant literature. Given the extent of the problem, the review will not be comprehensive but will focus on those

[1] In this context, the more suitable term is water "tariff" instead of water "price". In the economic sense, the price is created in the market, as result of the intersection between supply and demand. Since a water market in the agriculture sector does not exist in Andalusia and, therefore, it is not possible to speak about price in a strict sense, it is more correct to use the concept of "tariff". However, in the title we have decided on the word "price" because of its being a more colloquial term and in the text we use both indifferently.

[2] As a reference, we can compare this sum with the 0.19 €/m^3 at which water is bought by "Riegos de Levante" in order to irrigate the crops in Eastern Spain (www.abc.es., 25.01.06).

aspects of water management that are relevant to the problem at hand. These issues will include integrated water and economic variables analysis and, particularly, the relationship between the application of the water tariff in the agricultural sector and the effects of water reallocation. The attention will be on the papers that have developed and used a computable general equilibrium model to address these problems.

Some of the first studies and models that were used in order to integrate water and economic variables date from the 1950s, but operational difficulties limited the scope of their analyses. One of the first studies that overcame those obstacles was made by Lofting & McCaughey (1968). They introduced water inputs as a productive factor in a traditional input-output model in order to evaluate the water needs of the Californian economy. Later on we can find many works which analyze the relationship between water needs and the different productive sectors using input-output models (Sánchez-Chóliz, Bielsa & Arrojo, 1992; Bielsa, 1998; Duarte, 1999; Duarte, Sánchez-Chóliz & Bielsa, 2002; Velázquez, 2006; Dietzenbacher & Velázquez, 2007).

Several different methodologies have been explored in the analysis of water pricing (see, for example, the excellent reviews of Johansson et al., 2002; and Dinar and Subramanian, 1998). Many analysts have employed variants on linear programming approaches, such as those developed by Berbel & Gómez-Limón (2000) and Doppler et al. (2002) as well as input-output model applications such as the work of Sáenz de Miera (1998).

There is an extensive literature which has employed CGE models, and many studies with a similar objective to the one that is the focus of the present paper. One of the pioneers was an analysis by Dixon (1990), in which he offered indications to the public authorities of Melbourne, Sydney and Perth on appropriate water prices. Kumar and Young (1996) explained how a social accounting matrix (SAM) can be extended to incorporate water resources and analyze the implications of water pricing policies. In a similar way, Susangkarn and Kumar (1997) used a general equilibrium model to incorporate water as a separate productive sector. Decaluwé et al. (1999) developed a general equilibrium model to compare different water price policies as well as to analyze water production according to the use of different technologies. Seung et al. (2000a) used a CGE model to evaluate the impacts of water reallocation; in the other study of Seung et al. (2000b), they used a dynamic model to analyze the temporal effects of water reallocation from the agriculture sector to recreational uses in rural areas of Nevada. In a similar fashion, Briand (2004) developed a static CGE model to estimate the effects of a water price policy on production and employment in Senegal. Using a slightly different CGE formulation, Hewings et al. (2005) evaluated the impact of water reallocation from agriculture to other productive sectors in a recursive fashion that fully captured the feedback effects. The major impact here was on agricultural employment; the reallocation of water to more productive sectors (in terms of value added) could not compensate for the enormous net loss in employment. Finally and in the same line of the present work, Calzadilla et al. (2008) used a CGE analysis to capture the water scarcity and the impact of improved irrigation management.

2. Empirical approach

2.1. The model. The model comprises 16 productive sectors, derived from the 1990 input-output tables of Andalusia. The production technology uses a nested production function. The domestic output of sector *j*, measured in euros and denoted by Xd_j, is obtained by combining, through Leontief technology, the outputs (including energy) of the rest of the sectors and the value added VA_j. In turn, this value added comprises primary inputs (labor, L, and capital, K), combined using a Cobb-Douglas technology. The overall output of sector *j*, Q_j, is obtained from a Cobb-Douglas combination of domestic output and imports $Xrow_j$, according to the Armington hypothesis (1969), on which domestic and imported products are taken as imperfect substitutes.

The government[1] raises taxes to obtain public revenue, R (see André et al. (2005) for more information about the calculation of the taxes in the model), at the same time it makes transfers to the private sector, TPS, and demands goods and services, GD_j. PD yields the final balance (surplus or deficit) of the public budget:

$$PD = R - TPS\,cpi - GD_j\, p_j, \qquad (1)$$

where cpi is the consumer price index and p_j is a production price index before the application of a value added tax (VAT hereafter) referring to all goods produced by sector *j*. Tax revenues include those raised by an environmental tax.

Next, we are going to explain the introduction of water pricing. In the undertaken simulations, we adopt a taxation approach, including an environmental tax in the public revenue, R. Let Wd_j be the direct water consumption of productive sector *j*,

[1] In this model, the term *government* stands for local and regional administrations, as well as for those activities of the central government in the region and any institution that is more than half-financed with public funds.

expressed in cubic meters. If Y_j denotes the production value of sector *j*, we can assume a linear relationship between production and consumption:

$$Wd_j = \alpha_j Y_j, \quad (2)$$

where α_j is an indicator that measures direct water consumption for every euro of output produced in sector *j*. The technical parameter α_j accounts for the differences in water consumption intensities across sectors. Therefore, the agriculture sector pays an environmental tax of:

$$R_{WATER} = \sum_{j=1}^{16} wattarif_1 (1+\tau_1)(\sum_{i=1}^{n} a_{i1} p_i Xd_1 + $$
$$+((1+EC_1)wl_1 + rk_1)VA_1) +$$
$$+\sum_{i=1}^{16} wt_1 (1+t_1) rowp\, a_{rm1} Q_1 \quad , \quad (3)$$

where $wattarif_1$ is the water tariff for the agriculture sector; τ_1 is the production tax; a_{i1} is the agriculture sector technical coefficient; EC_1 is the payroll tax paid by employers; *w* is the wage; l_1 is the labor technical coefficient; *r*, is the capital price; k_1 is the capital technical coefficient; VA_1 is the value added; t_1 is the tariff; *row*, is the foreign price; a_{row1} is the foreign sector technical coefficient and Q_1 is the total output. All these parameters and variables are referenced for the agriculture sector.

The foreign sector is an aggregation of three great trade areas: the rest of Spain, Europe and the rest of the world. The balance of this sector is given by:

$$ROWD = \sum_{j=1}^{16} rowpIMP_j - TROW - \sum_{j=1}^{16} rowpEXP_j \, , \quad (4)$$

where IMP_j denotes imports of sector *j*; EXP_j exports of sector *j* and *TROW* transfers from abroad to the consumer. *ROWD* is the balance of the foreign sector.

The final demand comes from investment, exports and the consumption of goods derived from households. In our model, 16 different goods are considered – corresponding to the different productive sectors – as well as a representative consumer who demands present consumption goods and saves the remainder of his disposable income. The consumer income (*YD* henceforth) equals labor and capital income, plus transfers, minus direct taxes:

$$YD = w\,L + r\,K + cpi\,TPS + TROW -$$
$$- DT\,(r\,K + cpi\,TPS + TROW) -$$
$$- DT\,(w\,L - WC\,w\,L) - WC\,w\,L, \quad (5)$$

where *w* and *r* denote input (labor and capital) prices, and *L* and *K* the input quantities sold by the consumer; *DT* is the income tax rate and *WC* the tax rate that corresponds to the payment done on behalf of the employees to the Social Security System. The consumer's objective is to maximize his welfare, subject to his budget constraint. Welfare is obtained from consumption goods CD_j ($j = 1,\ldots,16$) and savings *SD* according to a Cobb-Douglas utility function:

$$\text{maximize } U\,(CD_1,\ldots,CD_{24}, SD) = \left(\prod_{j=1}^{16} CD_j^{\alpha_j}\right) SD^{\beta}, \quad (6)$$

$$\text{s.t.} \sum_{j=1}^{16} p_j CD_j + p_{inv}\,SD = YD\,,$$

p_{inv} is an investment price index.

Regarding investment and saving, this is a *saving driven* model. The closure rule is defined in such a way that investment is exogenous (INV_j), savings are determined by the consumer's decisions and both variables are related to the public (*DP*) and foreign sectors (*ROWD*) by the following identity:

$$\sum_{j=1}^{16} INV_j\, p_{inv} = SDpinv + PD + ROWD\,. \quad (7)$$

Labor and capital demands are computed under the assumption that firms minimize the cost of producing value added. In the capital market, we consider that supply is perfectly inelastic. In the labor market, there is a feedback between the real wage rate and the unemployment rate. This feedback somehow represents rigidities in the labor market that are related to the power of unions or other friction-inducing factors. Specifically, we consider the following labor supply function (see Kehoe et al., 1988):

$$\frac{w}{cpi} = \frac{1-u}{1-\bar{u}}, \quad (8)$$

where u and $\bar{u}$ are respectively the unemployment rates in the simulation and in the benchmark equilibrium. This formulation is consistent with an institutional setting where the workers decide the real wage taking into account the unemployment rate – according to equation (8) – and employers decide the amount of labor that will be employed.

The activity levels of the public and foreign sectors are fixed, while the relative prices and the activity levels of the productive sectors are endogenous variables.

The equilibrium of the economy is given by a price vector of all goods and inputs, a vector of activity levels, and a value for public income such that the consumer is maximizing his utility, the productive sectors are maximizing its profits (net of taxes), public income equals the payments of all economic agents, and supply equals demand in all markets.

2.2. Databases and calibration. The main data used in this paper come from the 1990 social accounting matrix for Andalusia (SAM hereafter, see Cardenete, 1998). Emission data are obtained from the 1990 environmental input-output tables for Andalusia (TIOMA90) elaborated by the regional environmental agency[1]. They show real observed data on different water consumption levels for 74 activity sectors. These data were aggregated into 16 to match the SAM structure. There is a more recent SAM for Andalusia but, unfortunately, there are no official water consumption data per sectors, disaggregated enough, for any other year after 1990; hence, we decided to use the SAMA90 for the sake of consistency.

The numerical values for the economic parameters are obtained by the usual procedure of calibration (see, for example, Mansur and Whalley, 1984). The following parameters are specifically calibrated: all the technical coefficients of the production functions, all the tax rates (except for the environmental tax) and the coefficients of the utility function. The direct water consumption coefficients α_j are obtained from equation (2), i.e., dividing the observed water consumption by the amount of output for every sector. The calibration criterion is that of reproducing the SAMA90 as an initial equilibrium situation for the economy, which is then used as a benchmark for all the simulations. In such an equilibrium, all the prices and the activity levels are set equal to one, so that, after the simulation, it is possible to observe directly the change rate of relative prices and activity levels.

The SAMA90 comprises 16 industry sectors, two inputs (labor and capital), a saving/investment account, a government account, direct taxes (IT and ESS) and indirect taxes (PT, VAT, output tax and tariffs), a foreign sector and a representative consumer.

3. Results

Applying the previous model, we have simulated changes in the water tariff on the agriculture sector, with five different scenarios, trying to erase part of subsidy with this exercise. Considering that the initial water tariff is 0.006 €/m^3, the scenarios are as follow: (1) increase from 0.006 €/m^3 to 0.01 €/m^3; (2) increase from 0.006 €/m^3 to 0.03 €/m^3; (3) increase from 0.006 €/m^3 to 0.06 €/m^3; (4) increase from 0.006 €/m^3 to 0.09 €/m^3; and (5) increase from 0.006 €/m^3 to 0.12 €/m^3. As it can be observed, these simulations assume that the water price is increased significantly, with a consequent potentially heavy sacrifice on the side of the farmers.

We have defined an indicator of direct water consumption (equation (2)), α_j, which quantifies the amount of water per euro in sector *j*. Comparing this indicator, before and after the implementation of the pricing policy, on each scenario (Table 1), we can affirm that this policy does not mean an improvement in meeting a water saving objective. When analyzing the first scenario, on which the price raises from 0.006 to 0.01€, we can see that, with such a small increase, water consumption in the agriculture sector per output unit produced decreases but a little (only a 0.02% in relation to the initial level). This slight reduction of water consumption could have two causes. First, the fact that water in Andalusia is paid according to the number of irrigated hectares and not to the amount actually consumed. Every farmer enjoys a water concession from the Water Regional Federation proportionate to the number of land hectares he needs to irrigate, and this concession is not altered in the short-term[2] by a price increase. Secondly, the small reduction of water consumption per output unit produced could be related to the impossibility, derived from the model suppositions, to modify irrigation technology. The price increase would induce the farmer to modernize his irrigation system, and thus reduce the amount of water consumed per unit produced. This, along with the concession of water per hectare – and assuming the concession is kept constant in the short term – would generate an increase in agriculture production. Nevertheless, we find ourselves in the opposite situation: before an increase of the water price in this sector, the impossibility to modernize irrigation technology and the immutability of the concession in the short term, the pricing policy would not reach the defined objective of reducing water consumption in this sector, transferring the costs increase to other sectors (as we will now see) thus provoking a reduction in their production.

Table 1. Indicator of direct water consumption (percentage variation from base case)

		1st	2nd	3rd	4th	5th
1	Agriculture	-0.02	-0.12	-0.26	-0.32	-0.47
2	Extractive industry	0.82	7.09	15.15	12.95	30.31
3	Water	0.00	0.00	0.00	0.00	0.00
4	Metallurgy	0.17	-0.46	-1.11	2.26	2.31
5	Construction materials	0.05	-2.41	-5.34	0.23	6.79
6	Chemicals and plastics	-0.05	0.32	0.18	-0.60	-2.46

[1] Nowadays, the Regional Environmental Department (Consejería de Medio Ambiente).
[2] Think that, on the average, concessions are given for 75 years.

Table 1 (cont.). Indicator of direct water consumption (percentage variation from base case)

7	Machinery	0.37	-18.40	-19.03	4.21	-337.07
8	Vehicles and transportation material	-1.22	-22.28	-33.66	-18.13	1.97
9	Agroalimentary industry	-2.32	3.19	13.60	-38.71	-13.19
10	Textile, apparel, footwear, leather prod.	-1.14	-3.80	14.83	-15.21	130.34
11	Lumber industry and paper	0.00	0.28	-0.41	-0.08	2.08
12	Other miscellaneous	-1.87	-104.60	-829.45	-19.81	-903.66
13	Construction	-0.15	1.83	-0.47	3.57	23.01
14	Trade, hotel and catering trade	-0.73	-4.16	-17.96	-8.30	-15.27
15	Transportation and communications	-0.07	-18.56	8.10	-36.62	-206.72
16	Other services	1.63	19.05	3.02	27.00	55.71

Source: Own elaboration.

On the other hand (and still analyzing the first simulation), it is worthwhile underlining the reduction of water consumption in the case of the agroalimentary industry (9), the textile industry (10), construction (13) and trade, hotel and catering trade (14). In previous studies (Velázquez, 2006) it has been proved that these sectors are the ones that present a higher indirect water consumption level, which means that they consume the most through the agriculture products they use as inputs for their respective productions. We have just set out the possibility of the farmer who, confronted with an increase of the water price, transfers that new cost to other sectors (in this case, the industry and services mentioned). Those sectors affected by an increase in their costs, via inputs, could find themselves induced to cut short their production (as it can be observed in Table 3 and will lately be discussed) and, along with this, to reduce the direct water consumption associated to this production.

To reduce the water consumption level per unit (Table 1), the reduction of the water consumption level should be relatively greater than the reduction experienced in the production. In such a case, although production would suffer, we could speak of a favorable change in terms of conservation of the resource.

And so it can be seen in Table 2, where we have reflected the elasticity of the direct water consumption level in relation to production

$$\varepsilon = \frac{\dfrac{wd_i}{\nabla wd_i}}{\dfrac{y_i}{\nabla y_i}}$$

in such a way that, if ($\varepsilon > 1$), the resulting reduction in the water consumption level is greater than the resulting reduction in production – and we could speak of an improvement from a resource saving point of view – and vice versa.

Table 2. Elasticity of the direct water consumption level in relation to production

		1st	2nd	3rd	4th	5th
1	Agriculture	1.001	1.007	1.015	1.021	1.029
2	Extractive industry	0.992	0.935	0.870	0.888	0.770
3	Water	0.000	0.000	0.000	0.000	0.000
4	Metallurgy	0.998	1.005	1.012	0.979	0.979
5	Construction vaterials	1.000	1.026	1.059	1.002	0.942
6	Chemical and plastics	1.001	0.999	1.002	1.013	1.034
7	Machinery	0.997	1.227	1.239	0.964	-0.424
8	Vehicles and transportation material	1.013	1.289	1.514	1.229	0.989
9	Agroalimentary industry	1.024	0.973	0.887	1.649	1.168
10	Textile, apparel, footwear, leather prod.	1.012	1.043	0.877	1.192	0.440
11	Lumber industry and paper	1.000	0.999	1.008	1.006	0.987
12	Other miscellaneous	1.020	-21.807	-0.138	1.260	-0.126
13	Construction	1.002	0.984	1.008	0.971	0.819
14	Trade, hotel and catering trade	1.008	1.046	1.225	1.099	1.192
15	Transportation and communications	1.001	1.230	0.928	1.586	-0.943
16	Other services	0.984	0.841	0.972	0.789	0.644

Source: Own elaboration.

As we have already pointed out, a favorable change in the above-mentioned sectors (mainly 9 and 10) would occur and we can see that a slight increase in the water price would improve the situation of most sectors from a water saving perspective. Nevertheless, as the increase of the water price rises, the reduction of water consumption associated to negative effects on production increases accordingly, and we can observe how, in the last simulation, only two sectors – the agroalimentary industry (9) and trade and hotel and catering trade (14) – in addition to the agriculture and chemicals and plastics sectors, would reach a better situation.

Going back to the results of Table 1 and analyzing the rest of the simulations, we can observe that, even with a larger tariff increase (0.12 €/m^3 in the 5th alternative), the water consumption level per unit produced in agriculture would only be reduced 0.47%. This means that, despite a large increase in the water tariff for the agriculture sector, the consumption would actually remain invariable[1]. Therefore, we could draw a first conclusion from this first analysis: a tariff policy consisting of an increase in the water price for the agriculture sector does not seem to be the most appropriate one, in principle, when the objectives aim at the conservation of the resource; and this could be due to the present concessions policy and, in the case analyzed, to the impossibility of actually setting out changes in the irrigation technology. It seems thus logical to acknowledge the necessity of reconsidering the concessions policy, on the one hand, and on the other, of matching tariff policies with those designed to encourage technological change.

Perhaps, the most interesting results are derived from the water reallocation analysis. We understand that the reallocation of a resource takes place when, before a specific policy, the resource moves from being consumed by one sector to being consumed by a different one. This reallocation occurs endogenously, i.e., the model adapts the water consumption levels in both sectors to reach a new equilibrium and thus maintain the total water consumption level of the set of economy as a constant.

Given the direct water consumption necessary to generate the production of a certain sector – denoted by us as total direct consumption (W_{Tdi}) – we can say that the price policy causes water reallocation if the total direct water consumption is reduced in this sector while it is absorbed by others. Be it so, we could quantify the sector reallocation by means of an indicator (β_i) defined as the variation between total direct consumption before and after applying the policy:

$$\beta_i = W_{Td_i(t=1)} - \frac{W_{Td_i(t=0)}}{W_{Td_i(t=0)}}.$$

If this reallocation indicator is negative, the sector will be consuming a lesser amount of water after applying the policy and, if it is positive, the sector will be consuming a greater amount.

As it is observed in Table 3, the water reallocation analyzed in average terms occurs mainly (avoiding the results of the sector other miscellaneous (12), a sector aggregation that distorts the analysis) from the machinery (7) and transportation and communications (15) sectors – and to a lesser extent from vehicles and transportation material (8), agroalimentary industry (9), trade, hotel and catering trade (14) and agriculture (1) – towards the extractive industry (2), textile, apparel, footwear and leather products (10), other services (16) – except for trade, hotel and catering trade – and construction (13). Note that, although it is certain that the water amount consumed in the agriculture sector is reduced after applying the price policy, this reduction is small (it does not reach 3% with the maximum tariff increase). Since the price increase has been applied solely on the primary sector, one might expect that the greater reduction in the water consumption would take place in this sector. However, this does not happen, probably due to the inelasticity of water demand in the agriculture sector, already mentioned.

It is interesting to discuss the case of sectors (14) and (9). As we saw in the previous analysis, these sectors are most affected by the increase of the water price in agriculture. It would be logical to think that they would transfer water, for we know how the reduction in the production could lead them to a reduction in water consumption. Therefore, the fact of transferring water – that could be understood as an "efficient" behavior from the water saving point of view – is not related to a greater efficiency in consumption but to a reduction in production. If we now add the fact that these sectors are considered to be the engine of the Andalusian economy, it would seem a bit discouraging to implement a policy which, given the discussed restrictions, leads to a reduction in production precisely in those sectors which are more relevant in the Andalusian economic structure. Nevertheless, as we will explain later on, there are other factors that need to be accounted for.

[1] Results are somehow erratic, especially those obtained in the 4th and 5th simulations. This could be due to the high increase of the water price which the internal structure might not be able to sustain, forcing an equilibrium where results are hardly possible to interpret in economic terms.

It is also interesting to point out the behavior of two other sectors – textile industry (10) and construction (13) – because of the opposite position they assume in relation to the previous two sectors discussed upon – they absorb the water transferred by these two – and because of their important role in the region's economy. As we have already seen, these sectors that could be reducing their production as a result of the tariff policy on agriculture are instead absorbing water. We can thus announce that this policy generates an "inefficient" behavior in relevant sectors (we will get back to this point later on).

Table 3. Water reallocation (percentage variation)

		1st	2nd	3rd	4th	5th	Average
1	Agriculture	-0.14	-0.72	-1.44	-2.08	-2.79	-1.44
2	Extractive industry	0.80	6.99	14.93	12.62	29.81	13.03
3	Water	0.00	0.00	0.00	0.00	0.00	0.00
4	Metallurgy	0.16	-0.50	-1.19	2.13	2.13	0.54
5	Construction materials	0.02	-2.55	-5.61	-0.20	6.15	-0.44
6	Chemical and plastics	-0.09	0.11	-0.25	-1.25	-3.30	-0.95
7	Machinery	0.34	-18.52	-19.28	3.73	-335.61	-73.87
8	Vehicles and transportation material	-1.26	-22.44	-33.93	-18.64	1.11	-15.03
9	Agroalimentary industry	-2.39	2.82	12.80	-39.36	-14.41	-8.11
10	Textile, apparel, footwear, leather prod.	-1.21	-4.12	14.04	-16.08	127.18	23.96
11	Lumber industry and paper	-0.04	0.11	-0.75	-0.60	1.37	0.02
12	Other miscellaneous	-1.93	-104.59	-824.53	-20.62	-892.79	-368.89
13	Construction	-0.18	1.65	-0.83	2.99	22.06	5.14
14	Trade, hotel and catering trade	-0.78	-4.40	-18.38	-9.00	-16.14	-9.74
15	Transportation and communications	-0.10	-18.69	7.74	-36.93	-206.01	-50.80
16	Other services	1.61	18.95	2.85	26.68	55.18	21.05

Source: Own elaboration.

What are the effects on the sector production? The results derived from the model for the five studied scenarios are provided in Table 4. Note that the price policy has but a little repercussion on the total production – there is an imperceptible difference in the first considered scenario (-0.66%), reaching a significant reduction solely before strong increases of the price (-10.03% and -13.44%). Nevertheless, as we have already commented, there is a reduction of the production in some of the more dynamic Andalusian sectors – agroalimentary industry (9); textile, apparel, footwear and leather products (10) and trade, hotel and catering trade (14) – because of their need of agriculture inputs. This fact would support the mentioned hypothesis about the rigidity of water consumption in the agriculture sector, linked to the impossibility for technical changes in the irrigation systems and the fixed concessions in the short term. This rigidity would push the farmer to consume the same amount of water he used before the price change. In others words, the water price increase would negatively affect the farmer costs: before the impossibility to reduce them by means of a reduction in water consumption, he would transfer them to the buyer, affecting the rest of the regional economy.

Table 4. Real production (percentage variation)

		1st	2nd	3rd	4th	5th
1	Agriculture	-0.12	-0.60	-1.18	-1.76	-2.34
2	Extractive industry	-0.02	-0.10	-0.19	-0.29	-0.39
3	Water	0.00	0.00	0.00	0.00	0.00
4	Metallurgy	-0.01	-0.04	-0.08	-0.13	-0.18
5	Construction materials	-0.03	-0.14	-0.28	-0.43	-0.59
6	Chemical and plastics	-0.04	-0.22	-0.43	-0.65	-0.86
7	Machinery	-0.03	-0.15	-0.30	-0.46	-0.62
8	Vehicles and transportation material	-0.04	-0.20	-0.41	-0.62	-0.84
9	Agroalimentary industry	-0.07	-0.35	-0.71	-1.06	-1.41
10	Textile, apparel, footwear, leather prod.	-0.07	-0.34	-0.68	-1.03	-1.37
11	Lumber industry and paper	-0.03	-0.17	-0.34	-0.52	-0.70
12	Other miscellaneous	-0.07	-0.34	-0.67	-1.01	-1.35
13	Construction	-0.03	-0.17	-0.36	-0.56	-0.77

Table 4 (cont.). Real production (percentage variation)

		1st	2nd	3rd	4th	5th
14	Trade, hotel and catering trade	-0.05	-0.25	-0.50	-0.76	-1.02
15	Transportation and communications	-0.03	-0.16	-0.33	-0.50	-0.67
16	Other services	-0.02	-0.08	-0.17	-0.25	-0.34
Total	-0.66	-3.31	-6.65	-10.03	-13.44	-13.44

Source: Own elaboration.

Finally, the efficiency in water consumption after the application of the price policy has been analyzed. This efficiency indicator will try to capture the water policy effects before the shock and after it, measuring the water consumption. We can say that the policy is efficient when the direct water consumption per unit produced, after the policy is implemented, is smaller than the water amount consumed before this measure was adopted. Along with this idea, we can define an efficiency indicator (δ_i) as the quotient between the indicator of water direct consumption after and before the policy ($\delta_i = \alpha_{i(t=1)} / \alpha_{i(t=0)}$). If this indicator is greater than one, then the direct water consumption per unit produced is greater after the policy is implemented than before, showing signs of inefficiency. In the opposite case we would be talking of an efficient situation.

Following this idea, looking at Table 5, we can see that agriculture (1) is the less efficient in the different point of views, as the same way as trade, hotel and catering trade (14). Sectors with higher efficiency are textile, apparel, footwear and leather products (10), services – excluded trade, hotel and catering trade (14), extractive industry (2) and construction (13).

To resume the results included in Table 5, we can see how a clear deterioration in the water consumption efficiency takes place in the set of the economy, changing from 1.04 in the first simulation to 1.82 in the last one. The greater inefficiency is due to the fact that the set of the economy consumes a greater amount of water per unit produced, while the price of this resource in agriculture increases. As our starting hypothesis states that the total direct consumption – corresponding to the set of the economy – must remain constant in order to facilitate the real location process, then the greater inefficiency could be explained through the fact that the increase of the water price in agriculture has provoked reductions in the production of several economic sectors (textiles, construction, trade, hotel and catering trade, agroalimentary industry, and particularly the later two) significant enough not to allow that policy to reach its objective of reducing water consumption per unit produced.

This fact has partly been explained earlier in this article: if sectors such as the textile (10) or construction (13) are reducing their production (Table 4) but need a grater amount of water per unit produced (5th simulation, Table 1) and thus are forced to absorb water (5th simulation, Table 3), they are necessarily behaving in an inefficient manner (5th simulation, Table 5).

On the other hand, sectors (9), (14), (1), etc., are also reducing their production (Table 4) but have managed to reduce their water demand per unit produced (Table 1) because the reduction of water consumption is greater that the reduction in production (Table 2), and they transfer their water surplus (Table 3) – their behavior thus considered efficient from a water saving point of view (Table 5).

Interesting reflections can be done through relating water reallocation with water efficiency (Table 6). In those sectors which "transfer" water in the reallocation process ($\beta_i < 0$) – machinery (7), vehicles and transportation material (8) and transportation and communications (15) – there is an efficiency improvement ($\delta_i < 1$). However, in those that "absorb" water ($\beta_i > 0$), – mainly textile, apparel, footwear and leather products (10), other services (16) and the extractive industry (2) – inefficiency increases ($\delta_i > 1$).

Table 5. Indicator of water consumption efficiency

		1st	2nd	3rd	4th	5th
1	Agriculture	0.99978	0.99877	0.99743	0.99676	0.99531
2	Extractive industry	1.00821	1.07091	1.15154	1.12948	1.30315
3	Water	0.00000	0.00000	0.00000	0.00000	0.00000
4	Metallurgy	1.00166	0.99537	0.98892	1.02263	1.02315
5	Construction materials	1.00049	0.97587	0.94658	1.00234	1.06787
6	Chemical and plastics	0.99953	1.00322	1.00183	0.99397	0.97545

Table 5 (cont.). Indicator of water consumption efficiency

		1st	2nd	3rd	4th	5th
7	Machinery	1.00368	0.81598	0.80967	1.04206	-2.37066
8	Vehicles and transportation material	0.98782	0.77719	0.66344	0.81871	1.01965
9	Agroalimentary industry	0.97682	1.03186	1.13601	0.61293	0.86812
10	Textile, apparel, footwear, leather prods.	0.98861	0.96205	1.14829	0.84791	2.30342
11	Lumber industry and paper	0.99996	1.00275	0.99595	0.99921	1.02079
12	Other miscellaneous	0.98134	-0.04601	-7.29448	0.80189	-8.03655
13	Construction	0.99854	1.01830	0.99533	1.03572	1.23010
14	Trade, hotel and catering trade	0.99270	0.95838	0.82035	0.91695	0.84725
15	Transportation and communications	0.99932	0.81443	1.08101	0.63384	-1.06717
16	Other services	1.01627	1.19053	1.03020	1.26996	1.55708
	Total economy	1.04	1.15	1.54	1.63	1.82

Source: Own elaboration.

Concerning the sectors with a greater repercussion on the regional economy, the ones we have mostly focused on in this study, we could define two separate groups: first those sectors that absorb water and which show an inefficient behavior after the implementation of the tariff policy – textile (10) and construction (13); and secondly, those other sectors which transfer water and behave efficiently when this policy is implemented – agriculture (1), agroalimentary (9), and trade and hotel and catering trade (14).

Finally we present social welfare effects of the policies presented. It always intereseting to analysis how various policies affect social welfare and whether the new equilibrium is socially efficient. Therefore we have incorporated in our CGE model a representative household. Using the equivalent variation as indicator, all consumers don't benefit from the reforms and this result is independent of the reform implemented. Anyway, the best situation is the third reform – increase from 0.006 €/m^3 to 0.06 €/m^3 – and the worst situation is the second one – increase from 0.006 €/m^3 to 0.03 €/m^3. In Table 6 we present these results.

Table 6. Social welfare indicator (equivalent variation after shocks)

	1st	2nd	3rd	4th	5th
Equivalent variation	-3553.79	-7259.58	-2688.55	-5422.48	-3372.34

Source: Own elaboration.

If we put these results in relation to the ones obtained in previous studies interesting conclusions are drawn. As we mentioned at the beginning of this work, Velázquez (1006) sets out the irrationality of the Andalusian intensive water consumption economy and proves that the agriculture, agroalimentary and tourism sectors (as well as construction, to a lesser degree) are the ones responsible for this situation. On the other hand, in a later work, Dietzenbacher and Velázquez (2007) prove that the Andalusian economy is a net water-exporting one; and the same sectors (agriculture, agroalimentary and tourism) are to be held responsible, in a greater degree than others, for this economic and ecological irrationality. If the tariff policy applied to the agricultural sector generates the reallocation of the resource from the abovementioned sectors to the ones that are lesser water consumers (which are also less export-oriented), this policy could contribute to conform more rationally the Andalusian economic structure and the regional water policy.

Table 7. Reallocation (β_i) – efficiency (δ_i) (average)

		Reallocation	Efficiency
1	Agriculture	-1.44	1.00
2	Extractive industry	13.03	1.13
3	Water	0.00	0.00
4	Metallurgy	0.54	1.01
5	Construction materials	-0.44	1.00
6	Chemical and plastics	-0.95	0.99
7	Machinery	-73.87	0.26
8	Vehicles and transportation material	-15.03	0.85
9	Agroalimentary industry	-8.11	0.93
10	Textile, apparel, footwear, leather prod.	23.96	1.25

Table 7 (cont.). Reallocation (β_i) – efficiency (δ_i) (average)

		Reallocation	Efficiency
11	Lumber industry and paper	0.02	1.00
13	Construction	5.14	1.06
14	Trade, hotel and catering trade	-9.74	0.91
15	Transportation and communications	-50.80	0.49
16	Other services	21.05	1.21

Source: Own elaboration.

Concluding remarks

In this work we have applied a CGE model to analyze the effects of an increase in the water tariff of the agriculture sector, aiming at the conservation of this resource, the efficiency in consumption and the possible reallocation of water among the different productive sectors. We have developed five scenarios, progressively increasing the tariff water on each of them, starting with the present level (0.006 €/m^3) and reaching a price of 0.12 €/m3. We have tried to capture if the effort that must be carried out in the agriculture sector could be compensated with a better water reallocation, reaching a greater efficiency in consumption and a better conservation of the resource.

The main conclusion drawn from this work is as follows: despite the tariff policy implemented in the agriculture sector not achieving a significant water saving level in this sector, a reallocation of the resource is achieved that seems to generate a more efficient and more rational behavior from a production point of view. This means that the reallocation produced from the agriculture, agroalimentary and tourism sectors to others where water consumption is not as basic leads to a less intensive water consumption production specialization, thus a more rational one, and to a reduced export of the resource.

It must be as well underlined that the limited effect of the simulated policy on the agriculture sector itself is probably due to institutional factors that condition its functioning (the concessions system, etc.). We also have to consider that the pointed out limitations of the model – regarding for example the impossible modernization of the irrigation system – could restrict the results and cut short the possibility of developing more real analyses.

Changes in technology, particularly in the irrigation systems, would likely have a significant impact on the total water amount used and the efficiency of that use in terms of water consumption per unit of production. Furthermore, the way in which price changes are mediated in the economy can also play an important role; for example, if real increases in the production costs occur as a result of water price increases, local (Andalusian) producers may not be able to pass along the cost increases under threat from (cheaper) imported products. Similarly, they may be limited in their ability to pass along the costs in products that are exported, for in belonging to a small region (and thus a price-taker) they are unlikely to affect changes in the regional prices.

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