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A Simplified Hydro-Economic Model of Guadalquivir River Basin for Analysis of Water-Pricing Scenarios

Borrego-Marín María M. [1,*], Expósito A. [2] and Berbel J. [1]

[1] Department of Agricultural Economics, University of Cordoba & WEARE research group, 14071 Cordoba, Spain; es1bevej@uco.es
[2] Department of Economic Analysis, University of Seville & WEARE research group, 41018 Seville, Spain; aexposito@us.es
* Correspondence: mmarbma@gmail.com

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Abstract: This study describes an economic model in the Guadalquivir river basin (Southern Spain) that considers inter-sectoral and hydrological effects of changes in water use as a response to various water-pricing policy scenarios. The main economic variables include water use, gross regional product, return flows in the river basin, and employment at sectoral and basin levels. The response of the different sectors to water pricing and of the sectoral productivity is derived from official data. The background of the model is based on previous research for the implementation of the UN System of Environmental-Economic Accounts and on the application of this framework to the Guadalquivir basin. Results based on the elicited curves illustrate that the structure of the demand function for irrigated agriculture passes from inelastic to elastic sections, while the function corresponding to the remaining economic sectors shows a continuous decreasing function with minor change in the elasticity structure of the curve. Results show that the impact of extreme measures of water pricing reduces water abstraction by up to 42% vs. the baseline scenario, with an economic reduction in regional Gross Domestic Product (GDP) of 1%.

Keywords: water pricing; water management; water policy; water-use efficiency; economic model; inter-sectoral; river basin

1. Introduction

Water scarcity and increasing inter-sectoral competition for available water resources exacerbate the need for an efficient and sustainable allocation of water. In this context, water-pricing policies have been considered as a suitable economic instrument to guarantee the efficient management of the resource and to deal with growing socio-economic pressure. A large body of literature has explored the effectiveness of water-pricing policies in managing demand in alternative sectors (households, industry, agriculture, etc.) and in achieving certain conservation goals (see, for example, [1–3]). Most water economists argue that price-based approaches towards promoting a more efficient use of water resources (especially in those locations suffering from water scarcity) and/or towards achieving conservation goals are more cost-effective than non-price-based approaches [4]. However, pricing reforms explicitly designed for these purposes are rarely observed. The work of [2] contains several case studies of water-pricing reforms over agricultural, industrial, and residential sectors, and arrives at the conclusion that certain political economy factors (such as the reason for the reforms, the interest and the parties involved, the existing institutions, and the power systems) prevent the implementation of theoretically efficient pricing reforms.

At European Union (EU) level, the Water Framework Directive (WFD) [5] requires EU Member States to implement economic instruments in order to manage water resources and to achieve a good environmental and chemical status of surface and groundwater bodies. Specifically, the Directive highlights the importance of estimating the economic value of water uses, the cost of the associated water services, and how much of that cost is recovered from users, and encourages the use of water pricing as a tool to achieve an efficient use of water. Nevertheless, little advance has been made in this direction. According to the Commission's Compliance Report [6] one of the main deficiencies in the WFD implementation involves the economic assessment of pricing measures and cost-recovery issues. Specifically, this report highlights the lack of methods for the calculation of costs (including environmental and resource costs) and benefits (including ecosystem services). Without these methods, neither will it be possible to ensure the implementation of effective pricing policies nor will disproportionate and inadequate measures be prevented.

Moreover, the WFD states that the level of cost recovery of water services should be analysed for certain water uses (including that of households, industry, and agriculture) and the characterization of water uses should refer to the basin as the level of management (Art. 5). Thus, the impacts of water-pricing should be both on a river basin scale and multi-sectoral. Finding ways to achieve positive economic outcomes in the management of water resources requires the aid of modelling tools to analyse the impact of alternative policy scenarios [7]. Following these recommendations, our model analyses not only the potential impacts of water-pricing policies (in various scenarios) on inter-sectoral water use and consumption, but also the effectiveness of these policies on the re-allocation of water between alternative uses within the river basin.

To this end, this study focuses on a strict economic point of view, since the main concept in order to determine water re-allocation among alternative uses is the economic concept of 'value'. The economic value of a given level of water consumption is driven by the benefit derived from its use. Water value changes with the quantity and type of use [8], and therefore monetizing water use enables a comparison to be made between uses and introduces clarity to the economic implications of water-management-related decisions. In a mature water economy [9], when demand exceeds supply, then another relevant concept is that of 'scarcity'. Water should be managed and allocated efficiently, that is, to maximize the value it provides to society. Under conditions of water scarcity, an economic focus, similar to that proposed in this study, helps identify efficient water allocations and reduce 'wasteful' practices. Additionally, the analysis of sectoral water demand and of its associated economic values of water facilitates the assessment of the effectiveness of public policies (i.e., water pricing), and identifies the trade-offs between resource uses.

There are numerous methods in the scientific literature for the assessment of the impact of re-allocation of water resources as response to economic policy measures, such as water pricing (see [10,11], among others). Nevertheless, studies have hitherto usually represented small spatial areas and/or addressed specific uses [12]. To the best of our knowledge, there are no studies available that analyse the effects of water-pricing policies on water use and consumption from a multi-sector approach and on a river basin scale where available water resources are depleted. This study aims to help fill this gap.

The proposed methodology simulates changes in water use for all relevant sectors in a river basin as the result of policy decisions regarding water-price measures. Price increases have been implemented by simulating various scenarios: baseline (current situation), financial and environmental cost-recovery scenarios, and two scenarios with major increases water costs. In order to test its applicability in a real context, the proposed methodology is applied to a specific case study: that of the Guadalquivir River Basin (GRB). The model requires a more detailed analysis of the irrigated sector, which is the greatest sector of consumption of water in the basin. The remaining economic sectors are taken into account via an estimation of water demand and economic productivity.

2. Materials and Methods

The Guadalquivir River Basin (GRB) contains 25% of Spain's irrigated land and it is the longest of the southern rivers (657 km); it can thus be considered one of the most important river basins in Spain.

It covers an area of 57,679 km^2 and contains a population of 4.3 million. The basin has a Mediterranean climate with a heterogeneous distribution of precipitation. The annual average temperature is 16.8 °C, and the annual average precipitation is 573 mm, with a range between 260 mm and 983 mm (standard deviation of 161 mm). The main land uses in the basin are forestry (49.1%), agriculture (47.2%), urban areas (1.9%), and wetlands (1.8%) [13] (Figure 1).

Figure 1. Guadalquivir River Basin District. (Source: Guadalquivir River Basin Authority (GRBA)).

The GRB is considered a mature closed basin where most of the water resources are already allocated across various uses (agricultural and non-agricultural) and there are growing pressures for new activities to use 'additional' resources such as reclaimed water and new reservoirs. The key factor influencing this situation is the agricultural sector, which is the largest user of water, with irrigated agriculture accounting for approximately 88% of total freshwater withdrawals in the basin. Due to its high irrigation efficiency (as a result of an intense modernisation of irrigation over recent decades), irrigated agriculture is competitive but still yields lower returns in comparison with other uses (industry, tourism, urban areas) in the basin. As water becomes scarcer, society turns to agriculture as a potential source of water, in the sense that this is the sector of major consumption and therefore efficiency of the use of water in the agricultural sector directly affects the availability of the resource.

The proposed methodology for the economic model estimates sector-specific demand curves because water demand may change with location (e.g., up-flow and down-flow agriculture) and type of water use (e.g., urban, industrial, agricultural). Therefore, the primary aim here is to assess the competing demands between different uses on a river basin scale. Additionally, the analysis will apply an economic approach to the assessment of the effects derived from alternative water-pricing scenarios where water demands constrain total use of the available resource within a one-period analysis, and hence it has a static nature. The methodology presented in this study reveals a deterministic approach since it considers a single-set of fixed boundary conditions (e.g., hydrological conditions) and parameters (e.g., constant price-elasticity of water demand). Therefore, no stochastic-determined variables are considered in the model.

Economic sectors are classified according the importance and the water-use typology. The proposed sectors of the demand for water services in the basin are:

(1) Agriculture

(1a) Rainfed agriculture

   (1b) Irrigated agriculture
   (1c) Livestock
(2) Households
(3) Industry
(4) Services
(5) Recreation
(6) Energy

The valuation of water depends on whether the resource is considered an intermediate or a final commodity [14]. Water demand as an input to a production process (e.g., irrigated agriculture) can be derived upon the isolation of the marginal contribution of water to the total output value, and therefore a deductive estimation approach is required. Deductive techniques usually employ mathematical programming, although general equilibrium models and residual value methods also fall within this category. When water is a final consumption commodity (e.g., urban demand), inductive valuation techniques based on the econometric or statistical analysis of observed data to estimate price-response may be more appropriate. In Guadalquivir, as explained in greater detail below, either type of analytical approach is used, depending on the sector analysed. Regarding the agricultural sector, a deductive value methodology has been considered as more appropriate in order to assess crop and location differences across the GRB. Regarding the remaining economic sectors, a valuation based on estimated price-elasticities of water demand enable us to obtain water-use demand curves relative to changes in water pricing.

Therefore, the methodology used in this paper is organised in the following three phases:

2.1. Baseline Definition: An Appropriate Characterisation of the Economic Sectors in the Basin

Various sources have been used either for the observed original data or for the estimation of non-observed variables when necessary. The baseline scenario (Table 1) has been defined by employing the gross domestic product and employment by sector statistics from the Statistical National Institute, and the sectoral water use and prices from the Hydrological Plan by the Water Agency [13]. Global water abstractions in the GRB are estimated at 3614 Hm^3 in 2012, where irrigated agriculture constitutes the greatest sector of consumption with 88% of the total water abstracted. Economic activities in the GRB generated around €66.1 × 10^9 in terms of GDP in 2012, which is equivalent to 7% of Spanish GDP. Over 73% of GDP in the GRB is concentrated in the service sector. Industrial activities amount to ≈18% of GDP, agricultural production ≈7%, and energy production ≈1%.

Table 1. Characterisation of the economic sectors in the basin. Guadalquivir 2012.

Sectors	Water Used (10^6 m^3)	GDP (10^6 EUR)	Employment (10^3 Person)	Price (EUR/m^3)
Rainfed Agriculture	-	1407	43	-
Irrigated Agriculture	3183.19	2585	79	0.060
Livestock	18.63	733	22	0.084
Households	261.00	-	-	1.900
Industry (non-energy)	68.00	12,175	228	1.112
Services	63.00	48,581	908	1.900
Recreation	1.00	10	0	0.025
Energy	19.00	626	12	0.049
Total	3613.82	66,117	1249	-

Source: Authors' own based on Statistical National Institute and [13].

2.2. Estimation of Demand Curves with Respect to Water-Price Changes for the Various Economic Sectors

2.2.1. Irrigated Agriculture Sector

The irrigation sector has been modelled by dividing the basin into two main areas (upper and lower basin) and by simulating demand curves in the current baseline scenario per crop area given the data available. Table 2 shows the characterisation of the irrigated agriculture sector (upper and lower areas) in the GRB in 2012. The upper area of the GRB is characterised by a more diversified crop pattern, while the lower area principally comprises olive groves (≈80%) and open-air vegetables (≈11%).

Table 2. Characterisation of the irrigated agriculture sector in the basin. Guadalquivir 2012.

Crops	Irrigated Area (ha)		Irrigated Area (%)		Water Use (m^3/ha)	Irrigated GM (€/ha)	Rainfed GM (€/ha)
	Upper	Lower	Upper	Lower			
Rice	38,698	0	8.98%	0.00%	10,450	787	0
Maize	16,697	2993	3.87%	0.70%	5000	1000	300
Winter cereals	64,149	11,740	14.88%	2.76%	1900	500	300
Cotton	58,813	3095	13.64%	0.73%	5000	1118	250
Sunflower	24,977	1315	5.79%	0.31%	2600	206	100
Sugar beet	12,780	673	2.96%	0.16%	4500	1765	300
Alfalfa	4950	3300	1.15%	0.78%	4500	1145	300
Vegetables (Open-Air)	35,184	46,000	8.16%	10.82%	4500	4911	250
Vegetables (Protected)	2265	0	0.53%	0.00%	4500	17,454	300
Citrus	38,476	3346	8.92%	0.79%	5400	1490	750
Grape	1650	1650	0.38%	0.39%	4000	2694	500
Olive (table)	34,644	0	8.03%	0.00%	1290	1265	400
Olive (oil)	60,920	324,510	14.13%	76.31%	1290	1480	550
Olive (intensive)	35,167	18,932	8.16%	4.45%	5000	1480	550
Almond	1800	6600	0.42%	1.55%	5000	2900	1150
Populous	0	1100	0.00%	0.26%	5400	500	400
Total	431,170	425,254	100.00%	100.00%			

Source: Authors' own based on [13].

The baseline price for irrigation is 0.06 EUR/m^3 (Table 1) with a variable tier of approximately 30% (0.02 EUR/m^3) and the rest as a flat rate. The agricultural sector's response to water pricing has been simulated by adjusting irrigated crop area (internally) and converting irrigated areas into rainfed crops when the water price causes irrigation to be halted. This is an oversimplification since certain intra-sector intra-regional water trade may be possible, but this option remains outside the scope of this analysis.

The threshold price that makes the crop unprofitable has been estimated by the algorithm shown below. The value of the threshold indicator is specific for each crop and zone. When this indicator takes a negative value, then the irrigation should be terminated. The algorithm is defined as:

$$DGM\ (Differential\ GM) = (Irrigated\ GM_{i,j}\ \text{-}\ Rainfed\ GM_{i,j}) \quad (1)$$

$$Stop\ irrigation\ when:\ (DGM_{i,j} - P_w Q_i) \le 0$$

where $GM_{i,j}$ = Gross Margin of crop i in the zone j; P_w= water price; Q_i =water use per hectare of crop i. Generally, the gross margins for any agricultural crop are determined by deducting variable costs from the gross farm income of a given crop for a given period of time (usually per year or per cropping season).

2.2.2. Non-Irrigated Economic Sectors

Once the current scenario is defined, the response of the different sectors can be simulated by using known elasticities of demand for the non-irrigated economic sectors. Thanks to [15], econometric approaches to estimate price-response and allocation effects from water-pricing changes have been widely used [16,17]. Nevertheless, the estimation of the water-price elasticity faces several challenges due to the existence of artificial price systems (such as, block-rate schedules) and to the variables and dataset used, among other shortcomings [11,18].

In the specific case of the GRB, the water use (abstractions) of non-irrigated economic sectors (i.e., energy, industry, services, and livestock) represents only 5% of the total water abstractions in the GRB, while that of households amounts to 7%. In order to simplify, this method uses price-elasticity estimates as appropriate instruments to model water-use demand curves. Moreover, and in the specific case of non-irrigated sectors, water-use demand functions are estimated by incorporating the following two assumptions:

- The use of price-elasticity estimates, as given by [19] and [20]. Constant-price elasticity forms are common in water management models, and provide a proxy to estimate consumer surpluses [21];
- The calibration of isoelastic demand curves by using estimated parameters upon a single point (Price, Water use) in year 2012 (latest contrasted data available).

Price elasticities of demand can be expected to be highly inelastic for non-irrigated uses, since there are few substitutes for water use in these economic sectors [22]. Thus, in our model, water for household, industrial, and service sectors can be expected to have a marginally higher value for a certain quantity of water consumed, since each unit of water is valued much more highly than that for irrigated agriculture and much less water is consumed [7].

Table 3 summarizes the estimates for the isoelastic demand equations, as well as parameter 'K', which is obtained by solving equation (2) for current water abstraction and price for each sector.

$$Q = Kp^{\varepsilon} \tag{2}$$

Elasticities (ε) for the different sectors can be found in Table 3, and have been assumed in accordance with [19,20].

Table 3. Estimated parameters for sectoral water demand. Guadalquivir 2012.

Sectors	Elasticity (ε)	*K* (Estimated)
Livestock	−0.29	9.11
Households	−0.22	300.58
Industry (non-energy)	−0.29	70.12
Services	−0.38	80.40
Recreation	−0.29	0.34
Energy	−0.89	0.37

Source: Authors' own based on [19,20].

The elicitation of each demand curve for each sector is illustrated by the following example, which corresponds to that of the household sector. This curve is calibrated by using the pair of known values (price = 1.9 EUR/m^3, and water use = 261 Hm^3 (Table 1)) for the year 2012, and by employing the elasticity parameter (−0.22) and the estimated *K* parameter for the household sector (300.58), as shown in Table 3. In this specific case, and for the sake of simplicity, no considerations regarding disposable family income have been made. The result is an elicited demand curve for the household sector in the GRB, as defined by the following expression:

$$Q = Kp^{\varepsilon} = 300.58p^{-0.22} \quad (3)$$

Once the demand curve (water use vs. water price) is estimated for each sector, an aggregated demand curve can be obtained from the horizontal sum of all individual (or sector-specific) elicited functions. The aggregated demand curve represents the water demand for non-irrigated sectors.

2.3. Analysis of Changes in Water Use and Allocation as a Consequence of Changes in Water-Pricing Policies

Economic evaluation of simulated scenarios can provide insights into benefits and inefficiencies of alternative policy decisions at an ex-ante stage [8]. Additionally, the development of various scenarios is of value because it provides a basis for discussion and a framework for strategic planning [7]. In order to assess the global impacts of water pricing on water use and consumption in various economic sectors, price increases have been carried out by simulating the following scenarios:

- Baseline (current situation)
- Financial cost recovery (FCR)
- Financial cost recovery + environmental cost (FCR+EC)
- FCR + EC + 150%
- FRC + EC + 300%

The values for the first two scenarios can be found in [23]. Financial cost-recovery instruments can be managed by public or private agents at various stages in the provision and management of water services. In order to calculate cost-recovery rates, it necessary to estimate what income public and private agents receive for the water services they provide. Based on the standard UN System of Environmental-Economic Accounts tables, cost-recovery ratios are computed by dividing the income generated from water services (as taxes, prices, or any other financial instrument) by the cost of their provision. The financial cost-recovery (FCR) index in the GRB in 2012 based on the UN System of Environmental-Economic Accounts is estimated at 75% for agricultural and livestock economic sectors, 87% for households and services, and 91% for industry. The environmental cost (EC) is defined as the cost of damage that the various water uses impose on the environment and ecosystems. The estimation of the environmental cost (EC) is defined by the Ministry of Environment and by the values for GRB found in the aforementioned hydrological plan [13]. The EC is estimated in the GRB in 2012 with an increase of 15% above the FCR. The latter two scenarios mean major price increases (of 150% and 300% respectively above FCR + (Ministry estimated) EC) in order to analyse the impact of extreme measures of water pricing.

The impact of changes in water use by irrigation that accounts for 88% of water use is not only concentrated in agriculture but also has a multiplier effect on the rest of the economy (mainly agri-food processing, but also other complementary industries) and on services (mainly transport and service providers to farms and food processing industries), which has been simulated by using the value found for California agriculture (similar to that of Guadalquivir) of 1.49, according to [24]. Due to this multiplier effect, when agricultural GDP (irrigation) increases by 1 EUR, then the GDP of the economy as a whole grows by 1.49 EUR (i.e., an additional 0.49 for the non-agricultural sectors).

3. Results

The proposed economic model has enabled demand curves to be elicited of water abstraction vs. water price increase in the alternative scenarios analysed in this study. Figure 2 shows the integration of demand curves (water use vs. water price) of irrigated agriculture (upper and lower areas) as well as the global (integrated) demand curve of the total irrigated agriculture in the GRB. The elicited curves illustrated that the structure of the 'lower agricultural irrigated' function, integrated basically by olives and open air vegetables, passes from inelastic to elastic sections, meanwhile the function corresponding to the 'upper agricultural irrigated', with a more diversified crop pattern, shows a continuous decreasing function with little changes in the elasticity-structure of the curve.

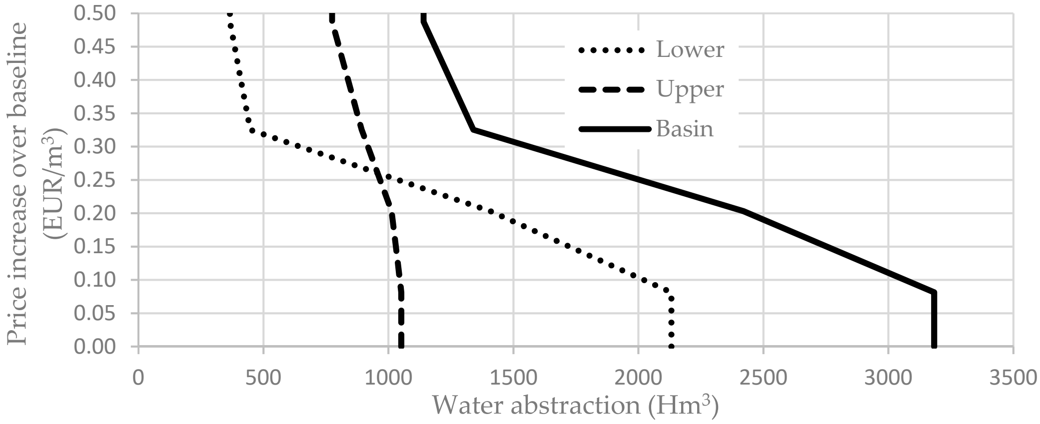

Figure 2. Elicited demand curves of water abstraction vs. water price increase (irrigation sector).

Figure 3 shows the integration of demand curves (water use vs. water price) of irrigated agriculture and the remaining economic sectors (non-irrigation), as well as the global (integrated) demand curve of the GRB. In this case, water abstraction excludes the inflow uses of energy (hydropower generation) and navigation uses. Hydropower has a lower priority in the GRB, since water is turbinated only when it is released for the interest of the other sectors, including environmental uses. Therefore, water available for hydropower is a by-product of decisions taken by the regulator in order to supply water to other sectors. In the case of navigation, this use is limited to the lower part of the GRB from the Atlantic Ocean near to Doñana National Park up to the inner-port of the city of Seville [13].

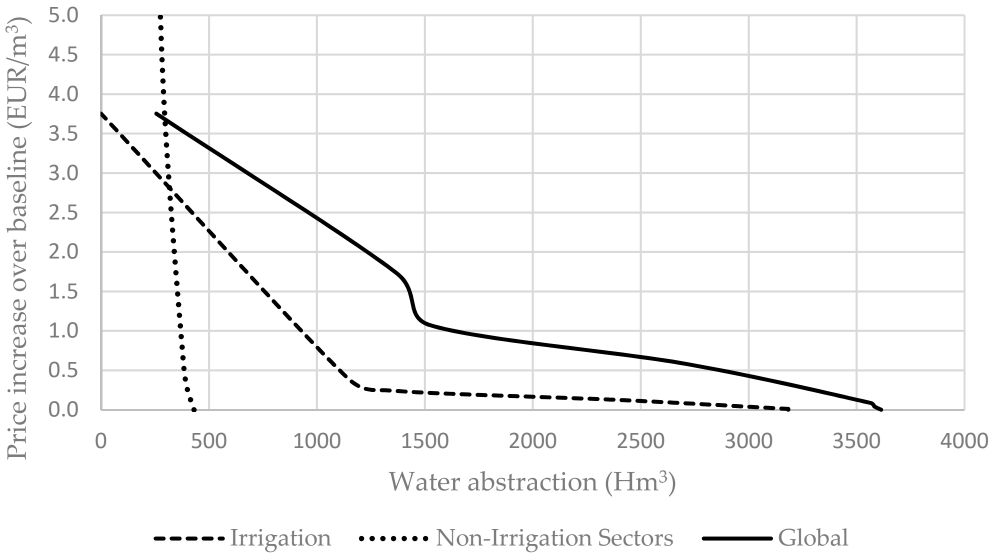

Figure 3. Elicited demand curves of water abstraction vs. water price increase (all sectors).

Based on the elicited curves, it can be clearly observed that the structure of the 'irrigated agricultural' curve passes from inelastic to elastic sections, while the curve corresponding to the remaining economic sectors (non-irrigation) shows a continuous decreasing function with minor changes in the elasticity structure of the curve.

Table 4 illustrates the response of water demand in all sectors as the water price increases as a response to the cost-recovery implementation.

Table 4. Estimated water withdrawal vs. scenarios of water pricing. Guadalquivir 2012.

	Gross Water Abstraction (hm^3)				GDP (10^6 EUR)			
	Irrigation	Non-Irrigation	Total	% Water	Agriculture	Non-Agriculture	Total GDP	% GDP
Baseline	3183	431	3614	100%	3992	60,742	64,781	100%
FCR	3183	399	3582	99%	3992	60,742	64,781	100%
FCR+EC *	3183	383	3566	99%	3992	60,789	64,828	100%
FCR+ EC * + 150%	2420	293	2713	75%	3988	60,656	64,715	100%
FCR + EC * + 300%	1266	256	1522	42%	3665	60,488	64,225	99%

Source: Authors' own. FCR = Financial Cost Recovery. EC * = Environmental cost defined by the Ministry of Environment [13].

Observation of Table 4 shows that the impact of extreme measures of water pricing reduces water abstraction by 42% vs. the baseline with the economic impact in regional GDP of a 1% reduction since agriculture (including livestock and rainfed agriculture), despite representing the sector most affected by the water pricing scenarios, constitutes only 7% of GDP. Results show that water pricing can induce water savings mainly by reducing water use in the irrigation sector although it should be considered that most of the socio-economic impact affects rural areas.

Table 5 shows the irrigated area per crop in the upper and lower areas in the various scenarios of water pricing. There is no change in the irrigation areas between the Baseline (Table 2), FCR, and FCR+EC scenarios because the increase of water pricing is insufficient to render the irrigated crops as unprofitable (inelasticity of the demand). The scenario for FCR + EC + 150% implies the substitution of crops, such as those of rice, winter cereals, sunflower, and populous, while the scenario for FCR + EC + 300% also affects maize, cotton, alfalfa, citrus, and olive (intensive) crops.

Table 5. Irrigated area per crop in the scenarios of water pricing.

Crops	Irrigated Area (ha) FCR		Irrigated Area (ha) FCR + EC *		Irrigated Area (ha) FCR + EC * + 150%		Irrigated Area (ha) FCR + EC * + 300%	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Rice	38,698	0	38,698	0	0	0	0	0
Maize	16,697	2993	16,697	2993	16,697	2993	0	0
Winter cereals	64,149	11,740	64,149	11,740	0	0	0	0
Cotton	58,813	3095	58,813	3095	58,813	3095	0	0
Sunflower	24,977	1315	24,977	1315	0	0	0	0
Sugar beet	12,780	673	12,780	673	12,780	673	12,780	673
Alfalfa	4950	3300	4950	3300	4950	3300	0	0
Vegetables (Open-Air)	35,184	46,000	35,184	46,000	35,184	46,000	35,184	46,000
Vegetables (Protected)	2265	0	2265	0	2265	0	2265	0
Citrus	38,476	3346	38,476	3346	38,476	3346	0	0
Grape	1650	1650	1650	1650	1650	1650	1650	1650
Olive (table)	34,644	0	34,644	0	34,644	0	34,644	0
Olive (oil)	60,920	324,510	60,920	324,510	60,920	324,510	60,920	324,510
Olive (intensive)	35,167	18,932	35,167	18,932	35,167	18,932	0	0
Almond	1800	6600	1800	6600	1800	6600	1800	6600
Populous	0	1100	0	1100	0	0	0	0
Total	431,170	425,254	431,170	425,254	303,346	411,100	149,244	379,433

Source: Authors' own. FCR = Financial Cost Recovery. EC * = Environmental cost defined by the Ministry of Environment [13].

4. Discussion

A recent report by the EEA [25] acknowledges the inelastic nature of water demand in many sectors: "price does not appear to be a significant determinant of water demand". The results obtained by our study are in line with this assumption. The 'lower agricultural irrigated' function, largely comprising olives and open-air vegetables, presents elastic sections, while the function corresponding to the 'upper agricultural irrigated' scenario with a more diversified crop pattern, shows a continuously decreasing function with minor changes in the elasticity structure of the curve. The same holds true with the remaining economic sectors (non-irrigation), including the household sector. Regarding the use of water price as an instrument to induce water saving in the household sector, the EEA in its review of eight EU countries [25] concludes that: "(..) in France, Germany and Spain, the results for the household sector suggest that the prices set have a relatively minor effect on the quantity of water demanded (i.e., water demand is inelastic to price)."

The Blueprint for the water strategy document [26] follows the dominant narrative (supported by environmental NGOs, political bodies, and research institutes) in the lines: "irrigation demand is inefficient because water cost is heavily subsidized and consequently, water is too cheap. When water price increases, the demand will be reduced and then sustainability is achieved." An example of this narrative can be found in reports issued by the European Environmental Agency (2013), which include statements such as: "(. . .) increasing irrigation water prices to meet full cost recovery would maximise water use efficiency" [27] (p. 34). However, this statement contradicts the empirical observation contained in the same document, which holds that water-conserving investments depend on "incentives generated by quantity constraints and the limited role of prices" [27] (p. 43). In our study, there is no change in the irrigation abstraction between the baseline, FCR, and FCR + (Ministry estimated) EC scenarios because the increase of water pricing is insufficient to render the sector unprofitable. Major price increase scenarios (150% and 300% respectively above FCR + (Ministry estimated) EC are necessary in order to decrease the gross water abstraction for irrigation. Our results are in line with those of [28] and [29], where the authors conclude that, in the case of irrigated agriculture for moderate price increases (i.e., water cost increases to reach financial cost recovery), the response is limited, and a disproportionate price increase is necessary.

Finally, it is worth mentioning that the proposed methodology presents several limitations. One such limitation originates from the fact that no transaction costs are considered, nor are social benefits and costs that have been derived from the re-allocation of the resource, since their estimation would involve considerable difficulties [21,30], and they therefore remain outside the scope of this study. Economic models enable the economic impacts to be analysed of different management policies or decisions (e.g., water-pricing). Although it is widely accepted that no single method can capture all the dimensions associated with allocating water across all its many uses and locations at a catchment level [30], findings should be treated cautiously since there may be an inevitable gap between modelling research and its application in decision-making. This gap could be minimised by the inclusion of this type of analysis in policy assessments of a more integrated and/or holistic nature [17,31], thereby analysing policies from broader perspectives and various angles [32]. Only in this way will decision-makers attain sufficient relevant information to successfully handle decision processes.

5. Conclusions

This research focuses both on the potential impacts of water-pricing policies on water use in various economic sectors in a Southern European river basin, and on the effect that these policies incur on the re-allocation of water between alternative uses within the river basin.

The WFD [5] adopts an integrated approach to water management and grants a critical role to economic instruments, such as the use of "water pricing" and "full cost recovery" (Article 9), as efficient measures to achieve environmental objectives. However, this study concludes that the role of prices remains limited regarding water-use reduction although it does remain a key instrument for achieving cost recovery for water services to ensure the maintenance and financing of existing and future water infrastructure.

The exploratory model developed herein may serve policy makers in their assessment of the potential effects of water-pricing policies on the water used and on consumption from an inter-sector approach.

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References

1. Espey, M.; Espey, J.; Shaw, W.D. Price elasticity of residential demand for water: A meta-analysis. *Water Resour. Res.* **1997**, *33*, 1369–1374. [CrossRef]
2. Dinar, A. *The Political Economy of Water Pricing Reforms*; Oxford University Press: New York, NY, USA, 2000.
3. Olmstead, S.M.; Stavins, R.N. Managing Water Demand. Price Vs. Non-Price Conservation Programs. A Pioneer Institute Water Paper. 2007. Available online: http://davismerchants.org/water/waterissues/pdf/Water%20Conservation%20study%20Harvard.pdf (accessed on 15 December 2018).
4. Olmstead, S.M.; Stavins, R.N. Comparing price and nonprice approaches to urban water conservation. *Water Resour. Res.* **2009**, 45. [CrossRef]
5. European Commission. Directive (2000/60/ec) water framework directive of the European parliament and of the council. *OJL* **2000**, *327*, 1–73.
6. European Commission. *Towards Sustainable Water Management in the European Union. First Stage in the Implementation of the Water Framework Directive 2000/60/ec. Accompanying Document to the Communication from the Commission to the European Parliament and the Council. Com (2007) 128 Final*; European Commission: Brussels, Belgium, 2007.
7. George, B.; Malano, H.; Davidson, B.; Hellegers, P.; Bharati, L.; Massuel, S. An integrated hydro-economic modelling framework to evaluate water allocation strategies i: Model development. *Agric. Water Manag.* **2011**, *98*, 733–746. [CrossRef]
8. Harou, J.J.; Pulido-Velazquez, M.; Rosenberg, D.E.; Medellín-Azuara, J.; Lund, J.R.; Howitt, R.E. Hydro-economic models: Concepts, design, applications, and future prospects. *J. Hydrol.* **2009**, *375*, 627–643. [CrossRef]
9. Randall, A. Property entitlements and pricing policies for a maturing water economy. *Aust. J. Agric. Resour. Econ.* **1981**, *25*, 195–220. [CrossRef]
10. Brouwer, R.; Pearce, D. *Cost-Benefit Analysis and Water Resources*; Edward-Elgar: Cheltenham, UK, 2005.
11. Young, R.A.; Loomis, J.B. *Determining the Economic Value of Water: Concepts and Methods*; RFF Press: New York, NY, USA, 2014.
12. Booker, J.F.; Howitt, R.E.; Michelsen, A.M.; Young, R.A. Economics and the modeling of water resources and policies. *Nat. Resour. Model.* **2012**, *25*, 168–218. [CrossRef]
13. Chg, C.H.d.G. *Plan Hidrológico de la Demarcación Hidrográfica Del Guadalquivir (2015–2021)-Anejo n°7*; Valoración Del Estado de Las Masas de Agua: Sevilla, Spain, 2015.
14. Gibbons, D.C. *The Economic Value of Water*; Routledge: Abingdon, UK, 2013.
15. Howe, C.W.; Linaweaver, F.P., Jr. The impact of price on residential water demand and its relation to system design and price structure. *Water Resour. Res.* **1967**, *3*, 13–32. [CrossRef]
16. Arbués, F.; García-Valiñas, M.a.Á.; Martínez-Espitildeñeira, R. Estimation of residential water demand: A state-of-the-art review. *J. Socio-Econ.* **2003**, *32*, 81–102.
17. Ward, F.A.; Pulido-Velazquez, M. Incentive pricing and cost recovery at the basin scale. *J. Environ. Manag.* **2009**, *90*, 293–313. [CrossRef] [PubMed]
18. Renzetti, S. Commercial and industrial water demands. In *The Economics of Water Demands*; Springer: Berlin/Heidelberg, Germany, 2002; pp. 35–49.
19. Reynaud, A. Modelling household water demand in Europe—Insights from a cross-country econometric analysis of eu-28 countries. In *JRC Technical Report EUR 27310 EN*; European Commission: Luxembourg, 2015.

20. Berbel, J.; Schellekens, J.; Expósito, A.; Borrego, M.M.; Montilla-López, N.M. Review of Alternative Water Allocation Options; European Commission, 2018. Available online: https://ec.europa.eu/environment/blue2_study/pdf/Task%20A4B%20Final%20Report_CLEAN.pdf (accessed on 15 December 2018).
21. Griffin, R.C. Valuing urban water acquisitions. *JAWRA J. Am. Water Resour. Assoc.* **1990**, *26*, 219–225. [CrossRef]
22. Renzetti, S. *The Economics of Industrial Water Use*; Edward Elgar Publishing: Cheltenham, UK, 2002.
23. Borrego-Marín, M.M.; Gutiérrez-Martín, C.; Berbel, J. Estimation of cost recovery ratio for water services based on the system of environmental-economic accounting for water. *Water Resour. Manag.* **2016**, *30*, 767–783. [CrossRef]
24. Medellín-Azuara, J.; MacEwan, D.; Howitt, R.E.; Sumner, D.A.; Lund, J.R.; Scheer, J.; Gailey, R.; Hart, Q.; Alexander, N.D.; Arnold, B. Economic analysis of the 2016 california drought on agriculture. In *Center for Watershed Sciences*; UC Davis: Davis, CA, USA, 2016.
25. European Environmental Agency. *Water Management in Europe: Price and Non-Price Approaches to Water Conservation*; 978-92-9213-875-2; EEA: Copenhagen, Denmark, 2017.
26. European Commission. *"A Blueprint to Safeguard Europe's Water Resources", Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*; European Commission: Brussels, Belgium, 2012.
27. European Environment Agency. *Assessment of Cost Recovery through Water Pricing*; ublications Office of the European Union: Luxembourg, 2013; Technical report No 16/2013.
28. Expósito, A.; Berbel, J. Why is water pricing ineffective for deficit irrigation schemes? A case study in southern Spain. *Water Resour. Manag.* **2017**, *31*, 1047–1059. [CrossRef]
29. De Fraiture, C.; Perry, C. Why is Irrigation Water Demand Inelastic at Low Price Ranges? In Proceedings of the Conference on Irrigation Water Policies: Micro and Macro Considerations, Agadir, Morocco, 15–17 June 2002.
30. Davidson, B.; Hellegers, P. Estimating the own-price elasticity of demand for irrigation water in the musi catchment of India. *J. Hydrol.* **2011**, *408*, 226–234. [CrossRef]
31. Ward, F.A.; Booker, J.F.; Michelsen, A.M. Integrated economic, hydrologic, and institutional analysis of policy responses to mitigate drought impacts in rio grande basin. *J. Water Resour. Plan. Manag.* **2006**, *132*, 488–502. [CrossRef]
32. Berbel, J.; Esteban, E. Droughts as a catalyst for water policy change. Analysis of Spain, Australia (mdb), and California. *Glob. Environ. Chang.* **2019**, *58*, 101969. [CrossRef]