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## The Debate on Water Policies: Evidence from Drought in Spain

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# The Debate on Water Policies: Evidence from Drought in Spain

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## Abstract

Water scarcity is a critical environmental issue worldwide, especially in arid and semiarid regions. In those regions, climate change projections suggest further reductions in freshwater supplies and increases of the recurrence, longevity and intensity of drought events. At present, one important question for policy debate is the identification of water management policies that could address the mounting water scarcity problems. Suitable policies should improve economic efficiency, achieve environmental sustainability, and meet equity needs. This paper applies an integrated hydro-economic model that links a reduced form hydrological component, with economic and environmental components to such issues. The model is used to make a direct comparison of three water management alternatives, water markets, water pricing and institutional policies, based on their economic, environmental and equity outcomes. The analysis is performed in the Jucar Basin of Spain, which is a good natural experiment for studying the policies to confront water scarcity and climate change. Results indicate that both institutional and water market policies are good instruments to smooth the economic damage costs of droughts, achieving almost the same social benefits. However, the environmental effects of water markets are worrying. Another important finding is that water pricing is the worst policy option not only in terms of private and environmental benefits but also in terms of equity.

**Keywords.** Water scarcity, Climate change, Water policies, Hydro-economic modeling, Economic and environmental benefits

## 1. Introduction

Water scarcity and water quality degradation are becoming widespread problems in most regions around the world. The reasons are the large increase in global water extractions in the last century from 600 to 3,900 km<sup>3</sup> driven by the intensive growth of population and income, coupled with a questionable performance of water governance and policies. The degradation of water resources is a threat to human water security and environmental biodiversity around the world, which so far has been addressed by large investments to ensure human security in medium and high income countries. However, the threats to natural ecosystems are hardly accounted for (Vörösmarty et al., 2010).

The massive ecosystem damages in basins such as Ganges, Indus, Nile, Yellow, Yangtze, Amu and Syr Darya, Tigris, Euphrates, Murray-Darling, Colorado and Rio Grande call for a reconsideration of the water institutions and policies used at present. The need for such reform is not only for protecting ecosystems, but also to substitute the escalating investments that ensure human security for better water management options.

The scale of the global growing overexploitation indicates that water mismanagement is quite common, and that sustainable management of basins is a complex and difficult task. At first, water scarcity resulted from surface extractions, but recently it is worsening because of the unprecedented depletion of groundwater brought about by falling pumping costs. Between 1960 and 2000, groundwater extractions rose from 310 to 730 km<sup>3</sup> per year pushing depletion up to 150 km<sup>3</sup> (Konikow, 2011). This staggering annual depletion ranges from 50 km<sup>3</sup> in the Indus-Ganges-Brahmaputra region to 24 km<sup>3</sup> in the USA, 13 km<sup>3</sup> in the Tigris-Euphrates region, and 9 km<sup>3</sup> in Northern China (NASA GRACE data estimations).

Water scarcity is increased gradually by the decisions on water extractions in river basins linked to land use and economic activities. The problems arising from water scarcity could become critical during drought periods. Climate change is projected to aggravate the severity and recurrence of drought events, especially in arid and semiarid regions (IPCC, 2014). In those regions, the combined effects of human-induced permanent water scarcity and climate change-induced droughts portend unprecedented levels of water resources degradation.

The sustainable management of water is quite challenging because of the different types of goods and services provided by water. These goods and services can be

classified as private goods, common pool resources, or public goods, depending on the degree of exclusion and rivalry in consumption among consumers. Treated drinkable water in urban networks is close to a private good (rivalry & exclusion), water in surface watercourses and aquifers is close to a common pool resource (rivalry & non-exclusion), while water sustaining ecosystems comes close to a public good (non-rivalry & non-exclusion) (Booker et al., 2012). The management of water is governed by public policies because pure competitive markets fail to account for the common pool and public good characteristics of water.

The objective of this paper is to contribute to the ongoing policy discussion to address water scarcity and droughts. A hydro-economic model of the Jucar basin in Spain is used to make a direct comparison of policies based on their economic, environmental and equity effects. Three policy alternatives are considered: (1) an institutional approach based on stakeholders' cooperation; (2) a water market policy; and (3) a water pricing policy. The assessment of the three policies provides information to stakeholders and decision makers about the tradeoffs between the policies in the allocation of water among sectors and locations. The paper is organized as follows. First, the three types of water policies are reviewed in section 2. Then, the Jucar River Basin is presented in section 3. Section 4 describes the modeling framework, and section 5 presents the drought and policy scenarios and the simulation results. Section 6 concludes with the summary and policy implications.

## **2. Types of policy instruments**

Economic theory offers three types of policy instruments that could account for the market externalities created by the common pool and public good characteristics of water. The first type is the "Pigou solution", which is based on taxation of water extractions (Pigou, 1920). This is the water pricing approach that is being implemented in the European Water Framework Directive (WFD) (EC, 2012). The second type is the "Coase solution", which is based on privatizing the resource and trading (Coase, 1960). This is the water market approach that has been implemented in Australia (NWC, 2011). The third type is the common property governance (Ostrom, 1990), based on the evidence that coercive government rules fail because they lack legitimacy and knowledge of local conditions. This is the institutional approach, where stakeholders themselves have to design the rules and enforcement mechanisms for the sustainable

management of common resources (Ostrom et al., 1999), although this approach has been mostly ignored by water authorities.

Mainstream water policies in some countries derive from the Dublin Statement on Water, which declares water an economic good (ICWE, 1992), and are based on so-called economic instruments such as water markets or water pricing. Besides the European Union and Australia, both water pricing and water markets are being considered at present for solving the acute water scarcity problems in China (Che & Shang, 2015).

These economic instruments work well when water exhibits private good characteristics such as in urban networks, but not so well when water exhibits common pool resource or public good characteristics. There is a strong consensus among experts that water pricing could achieve sizable gains in efficiency and welfare in urban and industrial water networks (Hanemann, 1997), although implementation could face technical and political difficulties. Irrigation water from surface watercourses and aquifers exhibits common pool resource characteristics, and the use of economic instruments requires transforming the resource into a private good. This transformation is quite difficult, especially in arid and semiarid regions under strong water scarcity pressures, and would require the support of stakeholders.

Irrigated agriculture is the largest user of water in most arid and semiarid regions, and plays an important role in sustaining rural livelihoods and ecosystems. During drought spells, the adjustments to the shortfall of water supply in basins fall mainly on irrigation activities, which consequently trigger considerable economic and environmental impacts, and social conflicts. One important question for future policy debates is the identification of potential water management policies in irrigation. Suitable policies should improve economic efficiency, achieve environmental sustainability, and address equity within contexts of scarcity, droughts and climate change. The debate here deals with the relative efficacy of the different approaches to allocate water in irrigation, including water pricing, water markets and institutional mechanisms.

Water pricing in irrigation, to achieve water conservation, has been the subject of debate since the 1990s. A string of the literature finds that irrigation water pricing has limited effects on water conservation (Moore, 1991; Sheierling et al., 2004), and some

authors indicate that water markets seem far more effective than water pricing for allocating irrigation water (Cornish et al., 2004). In contrast, Tsur et al. (2004) indicate that water pricing could achieve an efficient allocation of irrigation water.

In recent decades, the water market approach has been gaining ground in some parts of the world to allocate water in irrigation such as in Australia and Chile. Previous studies in the literature consider that water trading is a flexible and efficient way to address water allocation problems (Easter et al., 1998; Connor et al., 2009; Howitt et al., 2012). These studies indicate that water markets may increase water use efficiency, avoid the development of new costly water resources, and achieve significant welfare gains by reallocating water from crops with low to high marginal value of water. Numerous pre-requisites are needed for the design of well-functioning water markets such as the definition of water rights, the creation of legal and institutional frameworks for trade, and investments in infrastructure to facilitate water transfer (Dinar et al., 1997).

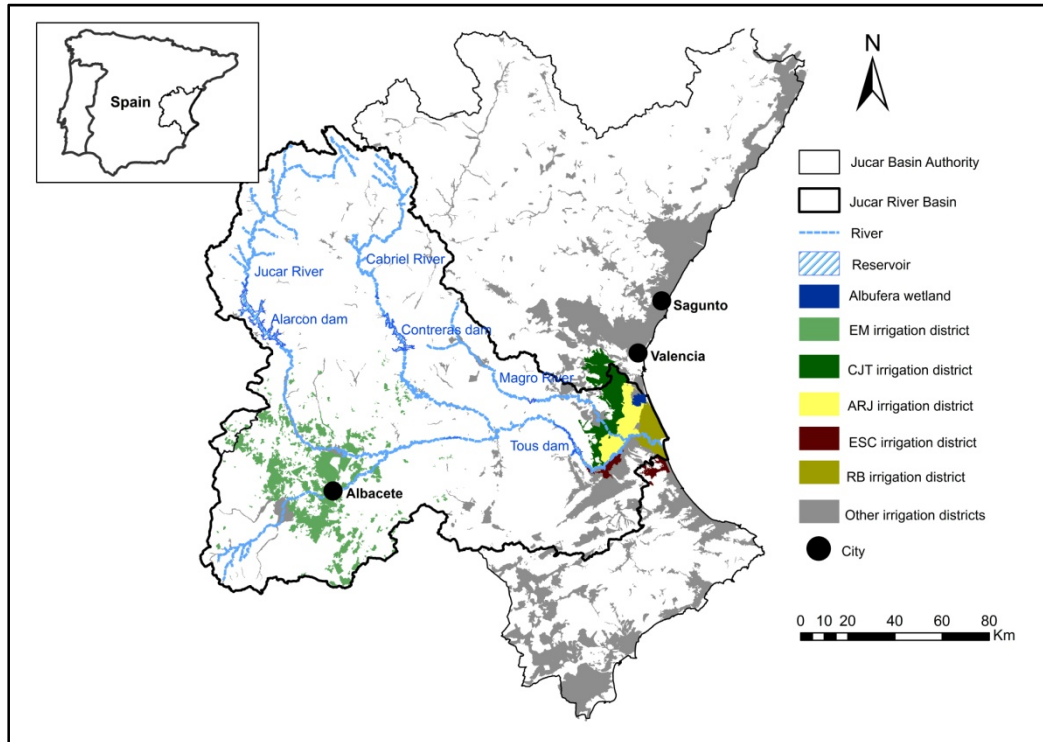
The Murray-Darling Basin is at present the most active water market in the world, and during the drought of 2002-2012 this market has generated benefits in the range of several hundred million to 1 billion US dollars per year (Connor & Kaczan, 2013). A challenge to water markets are the third party effects such as environmental impacts, which would reduce the benefits of trading. Water markets reduce streamflows because previously unused water allocations are traded, and also because gains in irrigation efficiency at parcel level reduce drainage and return flows to the environment downstream. This reduction in basin return flows has been analyzed both in Australia and the U.S. (Qureshi et al., 2010; Howe et al., 1986). Another worrying effect is the large surge in groundwater extractions, as shown in the last drought in the Murray-Darling.<sup>1</sup> The choice in Australia has been to mostly ignore the third party impacts of water markets (Connor & Kaczan, 2013).

Medellín et al. (2013) estimate very large potential gains from water trading under droughts or climate change in California. These gains in the Central Valley of California are estimated at 1.4 billion US dollars. However, implementing these potential gains from trading is quite a challenge as the failure of the Water Bank

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<sup>1</sup> Blewett (2012) indicates that extractions between 2002 and 2007 were seven times above the allowed limits placed on groundwater users.

Figure 1. Map of the Jucar River Basin.



experience in the 2009 drought shows. Water transfers were blocked by the water exporting regions and environmentalist NGOs (Medellín et al., 2013). The attainment of this solution seems to require stronger institutions, involving stakeholders' cooperation.

In Spain, the approach to water management is based on institutional arrangements and relies on the river basin authorities (CHE, 2008). The basin authorities are responsible for water management, water allocation, control and enforcement, planning and waterworks. The special feature of this institutional arrangement is the key role played by stakeholders in managing the basin authority.

Stakeholders are part of the basin authorities, taking decisions in the basin governing bodies and in local watershed boards, and they are involved at all levels of decision making: planning, financing, waterworks, measures design, enforcement, and water management. The management of water is decentralized, with the basin authorities in charge of water allocation, and water user associations in charge of secondary infrastructure and water usage. The main advantage of this institutional setting is that stakeholders cooperate in the design and enforcement of decisions, rules and regulations, and therefore the implementation and enforcement processes are carried on smoothly (Albiac et al. 2013).



Table 1. Water use by sector and origin in the JRB in a normal flow year (Mm<sup>3</sup>).

<b>Origin</b>	<b>Agriculture</b>	<b>Urban</b>	<b>Industrial</b>	<b>Total</b>
Surface water	761	118	24	903
Groundwater	633	104	25	762
Reuse	11	0	1	12
<b>Total</b>	<b>1,405</b>	<b>222</b>	<b>50</b>	<b>1,677</b>

Source. CHJ 2009.

Therefore, water allocation relies on the cooperation of stakeholders in basin authorities. Although water management in Spain is far from perfect, there have been recent mounting signs of successful experiences in the case of the La Mancha aquifers (Esteban & Albiac, 2012), where aquifer extractions have been curbed through stakeholders' cooperation.

### 3. The Jucar River Basin

The Jucar River Basin (JRB) is located in the regions of Valencia and Castilla-La Mancha in Eastern Spain. It extends over 22,300 Km<sup>2</sup> and covers the area drained by the Jucar River and its tributaries mainly the Magro and the Cabriel Rivers (Figure 1). The basin has an irregular Mediterranean hydrology, characterized by recurrent drought spells and normal years with dry summers.

The JRB renewable water resources are nearly 1,700 Mm<sup>3</sup>/year but water extractions are very close to renewable resources, 1,680 Mm<sup>3</sup>, and the basin is almost a closed water system. The main water use is irrigated agriculture with 1,400 Mm<sup>3</sup>, followed by urban and industrial uses of 270 Mm<sup>3</sup>, which supply households, industries, and services of more than one million inhabitants (Table 1). There are also non-consumptive uses for hydropower, aquaculture and recreation.

The irrigated area extends over 190,000 ha, and the main crops grown are rice, wheat, barley, garlic, lettuce, grapes, and citrus. There are three major irrigation areas located in the upper Jucar, the lower Jucar, and the bordering area of the Turia basin. The Eastern La Mancha irrigation area (EM) is located in the upper Jucar, covering 100,000 ha. The irrigation districts of Acequia Real del Jucar (ARJ), Escalona y Carcagente (ESC), and Ribera Baja (RB) are in the lower Jucar, with an area of 35,000 ha. The irrigation district of Canal Jucar-Turia (CJT) is located in the bordering Turia basin with an area of 22,000 ha (Table 2).

The expansion of water extractions in the basin and the severe drought spells in recent decades have triggered considerable negative environmental and economic

Table 2. The main water users in the JRB.

Water users	Water use (Mm <sup>3</sup> )		
	Surface water	Groundwater	Total
City of Albacete	17	0	17
EM aquifer irrigation district	13	386	399
Nuclear central of Cofrentes	14	0	14
City of Valencia	95	0	95
City of Sagunto	8	0	8
CJT irrigation district	70	91	161
ARJ irrigation district	213	0	213
ESC irrigation district	38	0	38
RB irrigation district	254	0	254
Other uses	193	285	478
<b>Total JRB</b>	<b>915</b>	<b>762</b>	<b>1,677</b>

Source. CHJ 2009.

impacts. The growth of water extractions in recent decades has been driven especially by subsurface irrigation from the EM aquifer. The aquifer depletion, combined with other important water extractions in the basin, and the recurrent drought spells have caused the water flows in the Jucar River to diminish. Environmental flows are dwindling in many parts of the basin, resulting in serious damages to water-dependent ecosystems. There have been negative impacts on the downstream water users. For instance, the water available to the ARJ district has fallen from 700 to 200 Mm<sup>3</sup> in the last 40 years. Consequently, the dwindling return flows from the irrigation districts in the lower Jucar have caused serious environmental problems to the Albufera wetland, which is mostly fed by these return flows (Garcia-Molla et al., 2013).

The Albufera wetland is the main aquatic ecosystem in the JRB. It is a fresh-water lagoon included in the RAMSAR list, and was declared a special protected area for birds. The Albufera receives water from the return flows of the irrigation districts in the lower Jucar, mainly from the ARJ and the RB irrigation districts, and other flows originate from discharges of untreated and treated urban and industrial wastewaters. There is an important water quality problem driven by deficiencies in the sewage disposal and treatment systems in the adjacent municipalities, and by the reduced flows originating from the Jucar River that used to improve the quality of wastewater discharges (Sanchis, 2011).

The increased frequency and intensity of drought spells during recent decades has been addressed by the Jucar basin authority with investments in several long-term adaptation measures, such as construction of storage and regulation facilities,

improvement of water efficiency through investment in irrigation systems, and installation of metering devices and special groundwater monitoring programs to control groundwater extractions.

#### 4. The Modeling Framework

The comparison of policies is based on the hydro-economic model developed in Kahil et al. (2015). The model includes three components: (1) a reduced form hydrological sub-model; (2) a regional economic sub-model consisting on irrigation districts and urban centers; and (3) an environmental benefit sub-model. The reduced form hydrological sub-model is used to link the different components of the river basin and to simulate the spatial hydrological impacts of droughts. The mathematical formulation of the reduced form hydrological sub-model is as follows:

$$Wout_d = Win_d - Wloss_d - Div_d^{IR} - Div_d^{URB} \quad [1]$$

$$Win_{d+1} = Wout_d + r_d^{IR} \cdot (Div_d^{IR}) + r_d^{URB} \cdot (Div_d^{URB}) + RO_{d+1} \quad [2]$$

$$Wout_d \geq E_d^{min} \quad [3]$$

where equations [1], [2] and [3] are the mass balance, the flow continuity, and the minimum-environmental flow constraints, respectively. These constraints determine the water available in the different river reaches that can be used for economic activities after considering the environmental restrictions.  $Wout_d$  is the water outflow from a river reach  $d$ ;  $Win_d$  the water inflow to  $d$ ;  $Wloss_d$  the loss of water in  $d$ ;  $Div_d^{IR}$  the water diversion to irrigation districts located in  $d$ ;  $Div_d^{URB}$  the water diversion to urban and industrial activities located in  $d$ ;  $Win_{d+1}$  the water inflow to the next river reach  $d + 1$ ;  $[r_d^{IR} \cdot (Div_d^{IR})]$  the return flows from irrigation districts;  $[r_d^{URB} \cdot (Div_d^{URB})]$  the return flows from urban and industrial activities;  $RO_{d+1}$  the runoff entering river reach  $d + 1$  from tributaries; and  $E_d^{min}$  the minimum environmental flow established for each river reach.

The regional economic sub-model accounts for the decision processes made by irrigation water users in the five major irrigation districts (EM, CJT, ARJ, ESC, and RB) and by urban users in the three main cities (Valencia, Albacete, and Sagunto). A farm-level programming component has been developed for each irrigation district, which maximizes farmers' private benefits from irrigation activities by choosing a crop

mix subject to various technical and resource constraints. A Leontief production function technology is assumed with fixed input and output prices, in which farmers are price takers. The optimization problem is given by the following formulation:

$$Max B_k^{IR} = \sum_{ij} C'_{ijk} \cdot X_{ijk} \quad [4]$$

subject to

$$\sum_i X_{ijk} \leq Tland_{kj} \quad [5]$$

$$\sum_{ij} W_{ijk} \cdot X_{ijk} \leq Twater_k \quad [6]$$

$$\sum_{ij} L_{ijk} \cdot X_{ijk} \leq Tlabor_k \quad [7]$$

$$X_{ijk} \geq 0 \quad [8]$$

where  $B_k^{IR}$  is farmers' private benefits in irrigation district  $k$ .  $C'_{ijk}$  is a vector of coefficients of net income per hectare of crop  $i$  using irrigation technology  $j$ . The net income of each crop is equal to revenue minus direct and indirect costs, and amortizations. The decision variable in the optimization problem is  $X_{ijk}$ , corresponding to the area of crop  $i$  using irrigation technology  $j$ . Crops are aggregated into three representative crop groups: cereals, vegetables, and fruit trees. Irrigation technologies are flood, sprinkler, and drip.

Constraint [5] represents the available area for irrigation equipped with technology  $j$  in irrigation district  $k$ ,  $Tland_{kj}$ . The water constraint [6] represents irrigation water availability in irrigation district  $k$ ,  $Twater_k$ , that depends on surface and subsurface water extractions for that district. Parameter  $W_{ijk}$  is gross water requirements per hectare of each crop  $i$  using irrigation technology  $j$ . The labor constraint [7] represents labor availability in irrigation district  $k$ ,  $Tlabor_k$ . Parameter  $L_{ijk}$  is labor requirements per hectare of crop  $i$  using irrigation technology  $j$ .

For urban water uses, an economic surplus optimization scheme has been developed for each city in the basin. The optimization problem maximizes social surplus given by the consumer and producer surplus from water use in each city, subject to several physical and institutional constraints. The optimization problem is:

$$Max B_u^{URB} = \left( a_{du} \cdot Q_{du} - \frac{1}{2} \cdot b_{du} \cdot Q_{du}^2 - a_{su} \cdot Q_{su} - \frac{1}{2} \cdot b_{su} \cdot Q_{su}^2 \right) \quad [9]$$

subject to

$$Q_{du} - Q_{su} \leq 0 \quad [10]$$

$$Q_{du}, Q_{su} \geq 0 \quad [11]$$

where  $B_u^{URB}$  is the consumer and producer surplus of city  $u$ . Variables  $Q_{du}$  and  $Q_{su}$  are water demand and supply by/to the city  $u$ , respectively. Parameters  $a_{du}$  and  $b_{du}$  are the intercept and slope of the inverse demand function, while parameters  $a_{su}$  and  $b_{su}$  are the intercept and slope of the water supply function. Equation [10] states that supply must be greater than or equal to demand. The quantity supplied,  $Q_{su}$ , is the connecting variable between urban use optimization components and the reduced form hydrological sub-model.

The environmental benefits sub-model accounts for the environmental benefits generated by the main aquatic ecosystem in the JRB, the Albufera wetland. The sub-model considers only water inflows to the Albufera wetland originated from irrigation return flows of the downstream ARJ and RB irrigation districts. Inflows and benefits of the Albufera wetland are given by the following expressions:

$$E_{Albufera} = \alpha \cdot r_{ARJ}^{IR} \cdot (D_{ARJ}^{IR}) + \beta \cdot r_{RB}^{IR} \cdot (D_{RB}^{IR}) \quad [12]$$

$$B_{Albufera} = \begin{cases} \rho_1 \cdot E_{Albufera} & \text{if } 0 \leq E_{Albufera} \leq E_1 \\ \delta_2 + \rho_2 \cdot E_{Albufera} & \text{if } E_1 < E_{Albufera} \leq E_2 \\ \delta_3 + \rho_3 \cdot E_{Albufera} & \text{if } E_{Albufera} > E_2 \end{cases} \quad [13]$$

where equation [12] determines the quantity of water flowing to the Albufera wetland,  $E_{Albufera}$ . Parameters  $\alpha$  and  $\beta$  represent the shares of return flows that feed the wetland from the ARJ and RB irrigation districts, respectively. The products  $[r_{ARJ}^{IR} \cdot (D_{ARJ}^{IR})]$  and  $[r_{RB}^{IR} \cdot (D_{RB}^{IR})]$  are return flows from the ARJ and RB irrigation districts, respectively.

Equation [13] represents economic environmental benefits,  $B_{Albufera}$ , from the ecosystem services that the Albufera wetland provides to society. The environmental benefit function is assumed to be a piecewise linear function of water inflows,  $E_{Albufera}$ , to the wetland. This function expresses shifts in the ecosystem status when critical thresholds of water inflows  $E_1$  and  $E_2$  are reached, following the approach of Scheffer et al. (2001). The reason is that ecosystems do not always respond smoothly to changes in environmental conditions, and they may switch abruptly to a contrasting alternative state for certain critical levels. Time series data of various hydrological and chemical indicators have been collected to characterize the ecosystem health status of the wetland (CHJ, 2009), along with economic valuation studies of the Albufera and other wetlands (Del Saz & Perez, 1999; Woodward & Wui, 2001; Brander et al., 2006).

The specification and estimation of the environmental benefit function is described in Kahil et al. (2015).

Detailed information on the technical coefficients and parameters of the hydro-economic model has been collected from field surveys, expert consultation, statistics, and reviewing the literature (GV, 2009; GCLM, 2009; INE, 2009; CHJ, 2009 and 2012; MARM, 2010). This information covers water inflows to the basin, water diversion to users, urban water prices and costs, efficiency of primary and secondary conveyance channels, crop yields and prices, subsidies, production costs, amortizations, crop water requirements, crop labor requirements, land and labor availability, and groundwater extractions.

## **5. Comparison of water policies**

The hydro-economic model is used to analyze the economic and environmental effects of the three alternative water policies designed to cope with scarcity and drought: the current institutional arrangement of the basin authority, water markets, and water pricing. The model provides results on the private benefits of users, environmental benefits, water use and return flows, and inflows to the Albufera wetland. Social benefits are assumed to be the sum of the private benefits from irrigation and urban use, and the environmental benefits (Table 3).

Two drought scenarios are considered, mild drought and severe drought. The reduction of water inflows over normal levels is 22 percent for mild droughts, and 66 percent for severe droughts. More information on the characterization of drought scenarios can be found in Kahil et al. (2015). The model simulates the outcomes of the three alternative policies to deal with these two drought scenarios.

*Institutional cooperation* is the baseline policy, and represents the current water management to cope with scarcity and droughts. This approach entails flexible adaptive changes in water allocations based on the negotiation and cooperation of users. The special feature of this approach is the involvement of water stakeholders in the decision making process, including the environmental concerns. The water allocations that result from cooperation are observed in the data from both normal and drought periods.

The *water market* policy opens up water trading between economic agents in irrigation districts and urban centers. Economic theory predicts that water markets

Table 3. Policies under drought scarcity: institutional, water markets, and water pricing.

Drought Scenario	Normal Year	Mild Drought		Severe Drought			
Type of Water Policy	Current situation (Cooperation)	Cooperation	Water markets and Water pricing	Cooperation	Water markets and Water pricing		
Water Use (Mm <sup>3</sup> )							
Irrigation districts	1030	908	908	683	683		
EM	399	359	363	304	316		
CJT	155	132	150	107	146		
ARJ	200	180	197	131	185		
ESC	33	30	32	18	31		
RB	243	207	166	123	4		
Urban use	119	105	105	74	74		
Environmental flows (inflows to Albufera)	60	52	50	34	29		
Private and Environmental Benefits (million Euros)							
	Current situation (Cooperation)	Cooperation	Water markets	Water pricing	Cooperation	Water markets	Water pricing
Private benefits							
Irrigation districts	190	171	175	93	136	148	54
EM	80	72	72	37	61	62	31
CJT	45	40	42	33	36	39	17
ARJ	34	31	32	17	23	25	4
ESC	7	7	7	5	4	5	2
RB	24	21	22	1	12	17	0
Urban use	283	276	276	276	241	241	241
Total	473	447	451	369	377	389	295
Environmental benefits	75	37	32	32	22	19	19
Social benefits	548	484	483	401	399	408	314

(Top) Water allocations to irrigation, urban use and environment in million cubic meters. (Bottom) Private benefits from irrigation and urban use, and environmental benefits in million Euros.

achieve welfare gains by reallocating water from low to high marginal values of water, and this efficient use of water maximizes the private benefits of agents. The model is used to test the water market policy alternative, and empirically estimate the market potential welfare gains. Water trade becomes more pronounced as drought severity intensifies, reaching 120 Mm<sup>3</sup> under severe drought. The main effect is the improvement of irrigation efficiency, but also the subsequent fall in irrigation return flows up to 19 Mm<sup>3</sup> which further reduce the environmental flows in the basin.

The *water pricing* policy achieves also the efficient use of water by adjusting water prices to balance water demand with the available water supply during drought. This policy alternative is in line with the water pricing policy advocated by the European Water Framework Directive, reiterated in the recent Blueprint to Safeguard Europe's Water Resources (EC, 2012). Water prices in each irrigation district and urban center are set equal to the marginal value of water at the efficient level of water use, which is the market-clearing price. One advantage of the *water pricing* policy is that it assures

the financial viability of the public and private water agencies responsible for water supply, which could guarantee its operation without the need of public subsidies.

Social benefits under the *institutional* or baseline policy in normal flow conditions amount to 548 million Euros. Private benefits are 190 million Euros for irrigation and 283 million for urban demand, from using 1,030 and 119 Mm<sup>3</sup> of water, respectively. Environmental benefits provided by the Albufera wetland are 75 million Euros, and the Albufera wetland receives 60 Mm<sup>3</sup> of return flows from the ARJ and RB irrigation districts, which support the ecological status of the wetland.

### 5.1 Mild drought scenario

Mild drought events reduce social benefits by 65 million Euros under the institutional and water market policies, but the social benefit losses go up to 150 million Euros under water pricing. The environmental losses are close to 40 million Euros under all policies, cutting environmental benefits by half. The difference among policies is the irrigation losses, which are below 20 million under institutional and water market policies, but escalate to 100 million under water pricing. Therefore the staggering benefit losses from the water pricing policy are driven by the large impact of pricing on irrigation profits.

The environment sustains significant benefit losses derived from the reduction of water inflows to the Albufera. These water inflows under water markets and water pricing fall below the critical threshold  $E_l$ , creating a regime shift in the wetland. The institutional policy achieves higher environmental benefits because it allocates more water to the Albufera, avoiding further desiccation and ecosystems degradation.

The effects on the urban sector are moderate both in terms of water allocations and private benefits. The reason is the priority rules under the institutional policy, and also the availability of additional water sources at higher costs from neighboring basins in the case of Valencia and Sagunto (Turia basin), or groundwater in the case of Albacete.

Farmers face diminishing water extractions from drought and reduce crop acreage, mostly of cereals because these are the less profitable crops. The allocation of irrigation water to the RB, ARJ and CJT districts changes between the institutional and water market policies. Water markets allocate 40 Mm<sup>3</sup> less water to RB, and this water is assigned to ARJ and CJT. These water exchanges are driven by the differences among



water shadow prices in districts. However, the private benefits of all irrigation districts are almost the same under both the institutional and water market policies.

The opportunity costs of policies for farmers are the benefit losses sustained under each policy. A steep increase in the opportunity costs of a particular policy would be met by opposition from farmers leading to policy failure, given that other feasible policies are less costly. The costs of the water pricing policy are very high for farmers compared to the institutional or water market policies, with irrigation benefits falling by half when water pricing is implemented instead of the other policies. Opposition to the water pricing policy would be strong in the RB, EM and ARJ districts, where the opportunity costs of implementing water pricing are especially damaging to farmers. This empirical finding shows that the institutional and water market policy options are much more feasible and equitable than water pricing, because water pricing involves disproportionate costs to farmers.

## 5.2 Severe drought scenario

The effects of severe drought are more pronounced than those of mild drought, although they show similar patterns. The fall in social benefits is almost 150 million Euros under the institutional and water market policies, but social benefits losses escalate to almost 250 million under water pricing. Environmental benefits sustain quite large losses, although the institutional policy allocates slightly more inflows to the Albufera.

The irrigation benefits by district are almost the same under the institutional and water market policies, and the main difference is the change in water allocation to the RB, ARJ and CJT districts. Compared to the institutional policy, water markets respond to the shadow prices of water. Water trading allocates more water to the ARJ, ESC, EM and CJT districts by reducing the allocation of the RB district by 120 Mm<sup>3</sup>.

Choosing the water pricing policy under severe drought is quite detrimental to farmers. The implementation of water pricing instead of the institutional or water market policies, make farmers lose two thirds of their private profits. In districts such as RB and ARJ, the private benefits of farmers are almost entirely wiped out. The opportunity costs for farmers of the water pricing policy are disproportionate.

The cost distribution of confronting a severe drought in the Jucar basin by the irrigation, urban and environmental sectors depends on the policy selected by decision

makers, and these costs are given by the benefit losses incurred by each sector. These costs are 42 million Euros for the urban sector (283-241) and 53 million for the environment (75-22) regardless of the policy chosen, but these costs triple from 50 million Euros (190-140) to almost 150 million (190-54) for the irrigation sector by selecting the water pricing policy instead of the other policies.

### 5.3 Additional measures to protect the environment

The environmental flows, especially during droughts, are a major concern in almost all basins in arid and semiarid regions. In these basins, regulators face a challenge to enforce environmental flows not only because they have to control surface and subsurface extractions, but also because the irrigation returns component of environmental flows is even more difficult to regulate than water extractions. Examples of these management difficulties include basins where water management efforts are quite sophisticated, such as the Jucar basin in Spain, the Murray-Darling basin in Australia, and the Central Valley in California.<sup>2</sup>

Two additional measures are considered for the JRB to protect environmental flows, one associated to water markets and the other to the institutional policy. The first measure follows the example of the Murray-Darling basin, where a very expensive program is being implemented to recover water for the environment using a public water buyback program. This seems to be a suitable policy to reap the private benefits of pure water markets while protecting ecosystems, and this is called the environmental water market. The second measure is to improve the current institutional stakeholder cooperation in Jucar, by including the environment as a full stakeholder. These augmented environmental flows are achieved by the negotiation among all economic and environmental stakeholders, which is called the sustainable institutional policy.

Both the environmental water market and the sustainable institutional policies achieve large gains in environmental benefits, above 200 Million Euros in mild and severe droughts, with social benefits in the basin reaching around 730 million Euros under mild drought and 660 million Euros under severe drought (See Kahil et al., 2013 and 2015, for details).

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<sup>2</sup> In the Jucar, there was a desiccation of the Jucar riverbed during the last drought. In the Murray-Darling basin groundwater depletion reached 104 km<sup>3</sup> during the last drought (Blewett 2012). In the Central Valley of California groundwater depletion has reached 80 km<sup>3</sup> during the current drought (UCCHM, 2014).

## **6. Conclusion**

The increasing pressures on water resources from economic and population growth are aggravating water scarcity problems worldwide, which result in serious damages to valuable water-dependent ecosystems. Climate change is also becoming a disruptive driver of the water cycle, contributing to worsening water scarcity in arid and semiarid regions. The sustainable use of water resources requires a reliable understanding of the main processes, an accurate assessment of impacts, and improving management by stakeholders and governance by policy makers to deal with water scarcity, droughts and climate change. Sound management and governance is quite a challenge because of the different types of goods and services provided by water, which could be private goods, common pool resources, and public goods.

This paper presents an empirical assessment of three water policy instruments to address water scarcity and droughts: water pricing, water markets, and common property governance. A direct comparison of the three policies is made by using a hydro-economic model of the Jucar basin in Spain, analyzing the economic and environmental effects of each policy.

Water pricing and water markets are economic instruments that work well when water is a private good, but less well when water is a common pool resource or public good. Studies in California and Australia demonstrate the large gains of water markets, both potential gains in California (Howitt et al., 2012; Medellín et al., 2013) and real gains in Australia (Connor & Kaczan, 2013).

We present evidence from Spain because the policy approach is institutional, with a strong tradition of cooperation among stakeholders in water user associations dating back centuries. Evidence from Spain regarding policy instruments is derived from the Jucar basin, where water markets, water pricing, and institutional policies are simulated under drought.

The empirical results highlight that both institutional and water market policies are good instruments to smooth the economic damage costs of droughts, achieving similar social benefits in terms of private and environmental benefits. This finding is important because it shows that in the case of Jucar, the institutional policy can attain almost the same private benefits as water markets.

The advantages of water markets compared to the institutional policy are a slight reduction in land fallowing, a small improvement in irrigation efficiency, and a more evenly distribution of drought losses among irrigation districts, thus addressing equity concerns. Water markets achieve the optimal private benefits but disregard the environmental benefits. Results show that water markets entail a reduction of water for environmental purposes, causing faster ecosystem regime shifts compared to the current institutional setting. The reason is the public good characteristic of environmental flows which are external to markets, leading to excessive depletion and ecosystem degradation. This is critically important when planning for a future with climate change and emerging social demands for aquatic ecosystem protection.

Water pricing is the policy advocated by the European WFD. This policy poses important challenges in arid and semiarid regions such as Spain, where irrigation is the largest user of water, having strong links to a wide range of ecosystem services. The water pricing policy for managing drought is very detrimental to farmers. Implementing water pricing instead of water markets or institutional policies, increases farmers' losses substantially by 80 and 100 million Euros under mild and severe drought, respectively.

These benefit losses are the opportunity costs of the water pricing policy to farmers, and the steep opportunity costs of water pricing would surely lead to policy failure. The main empirical finding on water pricing is that farmers lose from half to two thirds of their private benefits when the water pricing policy is implemented during drought, instead of the water market or institutional policies. Enforcing water pricing will become a quite difficult task facing tough political and technical hurdles.

The empirical results show that water market and institutional policies are much more feasible and equitable than water pricing, because water pricing involves disproportionate costs to farmers. There are also additional measures for these two policies that could enhance the protection of environmental flows. One measure is public water buyback programs for water markets, in order to reap the benefits of water markets while protecting ecosystems. The other measure is greening the cooperation in the institutional policy, by including the environment as a full stakeholder in the process of water allocation among sectors and spatial locations. However, protecting the environment with water pricing will require adding further "environmental" and

“resource use” costs to water prices (in WFD terminology), resulting in extreme disproportionate costs to farmers.

Water management in the JRB is based on the negotiation and cooperation of stakeholders, which seems to provide a worthwhile prospect for sustainable water management in irrigation. In fact, this approach achieves better environmental outcomes compared to other policy instruments, and almost the same outcomes in terms of farmers’ private benefits and social benefits compared to water market policy. However, the institutional-based approach is not easy to implement in real-world situations. The reasons are that institutions may involve asymmetric negotiation power among the stakeholders, and also the severe scarcity of water resources may considerably reduce the incentives for cooperation.

The evidence from the JRB highlights that, despite these limitations, the institutional-based approach was able to reduce environmental and economic damages during the last drought period, and to surrogate social conflicts by cooperation. The JRB experience suggests that the implementation of the institutional approach in managing water resources requires sufficient institutional capacity to deal with power asymmetry and resource scarcity, and available social capital supporting cooperation, which is particularly necessary for the promotion of self-regulation initiatives.

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