Water pricing policies, public decision making and farmers' response: implications for water policy

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Abstract

The problems caused by water scarcity demand important changes in the criteria and objectives of water policies. The agricultural sector in Spain consumes up to 80% of all available hydric resources and the need to increase the efficiency of current uses of water in the agricultural sector is at the core of the country's national water policy. One alternative would be to resort to water pricing policies with the aim of providing incentives to save water consumption although it would inflict a certain degree of income losses to the farmers and raise the revenue collected by the water authorities. The objective of this research is to analyze the effect caused by the application of different water pricing policies on water demand, farmers' income and the revenue collected by the government agency. To undertake this analysis a dynamic mathematical programming model has been built that simulates farmers' behavior and their response to different water pricing scenarios. Empirical application of the model has been carried out in several irrigation districts in Spain covering varied farm regions and river basins. Results show that the effects of alternative pricing policies for irrigation water are strongly dependent on regional, structural and institutional conditions and that changing policies produce distinct consequences within the same region and water district. Thus, equivalent water charges would create widespread effects on water savings, farm income and collected government revenue across regions and districts. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

Water is becoming an increasingly scarce resource in many regions and countries. Past common policies in many countries have fostered the development of irrigation and attempted to guarantee the supply of water to the residential users. Spain has followed along the political objectives developed in the past by the western US, Israel, Australia and more recently

Turkey. Resulting from these expansionary policies are the stressful situations in which water is massively consumed by the agricultural sector at a heavily subsidized cost and physical scarcity. These problems can hardly be solved with further investments and therefore, water scarcity has become an increasing social and economic concern for the public administrations and competing water users (e.g., rural, urban, industrial and 'environmental' users). Spain is not an exception and the degree of maturity to which the Spanish water economy has grown in recent times

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demands radical changes in the criteria and objectives pursued by water policies. Agriculture is becoming the focus to which all analysts are pointing as the culprit of the nation's water problems as well as capturing most of the attention to introduce better policies aiming at increasing water use efficiency. No wonder, a 10% improvement in the agricultural water use is almost equivalent to all current urban consumption (González-Romero and Rubio, 1993).

The institutions that control the allocation, delivery and management of irrigation water resources on one side, and the farmers who exercise their rights to use these resources on the other side, have become the center of the national debate. In this context, it has been considered that demand side water saving policies can increase the efficiency of irrigation water use in different institutional frameworks (Cummings and Nercissiantz, 1992). In several countries which have to face the problems of water scarcity, one of the key policy instruments that has been analyzed in the literature is the establishment of water prices to determine the patterns of response in the use of water in agriculture (Wilchens, 1991; Cummings and Nercissiantz, 1992; Rosegrant et al., 1995).

Water ownership in Spain belongs to the public domain and water allotment rights are assigned through government concessions to individual irrigators under a rigid non-tradable water rights system. As in most other regions and countries of publicly developed water districts, irrigators in Spain are charged water fees that correspond exclusively to the costs incurred in the construction and maintenance of conveyance and storage facilities. In fact, only around 15% of the cost of these publicly financed irrigation systems is being transferred to the irrigators (Martín Mendiluce, 1993) resulting in highly subsidized water charges.[1]

The discussion, in Spain and elsewhere, relates to the potential savings that might come along with charging additional water fees. Administered pricing of water is one of the policy instruments implemented to value water at its opportunity cost level, and its potential possibilities and limitations have been dis-

cussed in varied economic settings (OECD, 1987; Sampath, 1992; Rosegrant and Binswanger, 1994). Putting aside the legal difficulties that might arise with the incorporation of a scarcity rent's component in the price of water, there remain doubts as to whether these centralized water prices would be cost effective and produce the desired level of water savings. It has been argued around the difficulties that a water authority has to face to design and enforce a system of administered prices that will ensure a more efficient management of water resources (Randall, 1981). Strong political pressure will arise undoubtedly and will give way to forceful conflicts from situated irrigators operating under a water right system (Boggess et al., 1993; Moore et al., 1994) as they capitalize into their higher land values the subsidized water rights (Rosegrant and Binswanger, 1994). However, when water scarcity becomes a leading issue analyzing and understanding the effects of water prices on water saving becomes a decisive contribution for policy analysis (Moore et al., 1994). Although, it has been discussed also that the higher water prices induce the adoption of water-saving technologies (Caswell and Zilberman, 1985, 1990), we argue, however, that there are other factors that may outweigh these pricing effects. Some of these are the crop diversification potential in a given area of cultivation, the magnitude of the water allotment (i.e., resource endowment), the risk involved in water delivery (i.e., the irrigator's guarantee of receiving his entitled water allotment) and water quality. These factors have to be taken into consideration to analyze the potential effects that a given pricing policy may produce on the adoption of water saving technologies and to what extent these policies will provide incentives to the farmers to engage in water saving strategies.

Following this context, this paper will analyze the farmers' behavior in different administered water pricing scenarios. We are interested in studying what will be the effects of the application of different pricing schemes for water delivery on the demand for irrigation water, on farmers' income and on the revenue collected by the government agency. In particular, this paper will address the changing strategies that farmers will follow, like changes in the irrigation techniques, management of water in the farm, cropping technologies, crop selection shifting to less water

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[1]Estimates show that water is delivered in the Spanish irrigation districts at an average fee of 0.7 pta/m^3 while the average cost is estimated around 5.8 pta/m^3. (Naredo and Gascó, 1995). 1US$=125 pta (1996).

intensive crops or land allocation between irrigated and dry farming. All these issues are the cornerstones of our analysis. In sum, knowing the farmers response to these new policies will indeed illuminate the decision making process of policy choice to attain the desired goals of reducing water demand and alleviating water scarcity. This paper builds on preliminary work by the authors adding more complexity and empirical scope (Blanco et al., 1996; Garrido et al., 1997).

2. Analytical framework

To analyze the consequences of the application of alternative pricing policies for irrigation water, we have built a mathematical programming model (MPM) that simulates the farmers' behavior. Empirical application of the model is being conducted in a wide array of different situations to allow the regional and structural comparisons which will serve in turn as the baseline for policy implications. Farmers' behavior has been characterized by a selection of a set of 17 statistically based representative farms in six different irrigation districts covering three varied farm regions in Spain. These selected farms represent a comprehensive variety of water scarcity levels, patterns of water use, irrigation methods and water management institutions as well as farming systems, cropping selection and technologies. The agronomic data base of the model (including all water parameters) has been obtained from an ample survey conducted in 1995 and 1996 in the regions involved which correspond to four different river basins (Sumpsi et al., 1997). These regions are namely, Castille in the northern central plateau of Spain, Andalucia in the south and Valencia in the Mediterranean coastline. Farming patterns range from small scale family farming of limited crop diversification, to large scale commercial agriculture, fruit trees plantations and orchard intensive farming with high value added crops for the domestic and export markets.

2.1. The model

The MPM is a dynamic farm model of constrained optimization that resembles the model used by Weinberg et al. (1993) in which the farmer maximizes his profit function considering his technical constraints (availability of land, labor, equipment, production possibilities), financial constraints (liquidity and loans), economic constraints (prices of inputs and products, rates of interest) and policy constraints (Common Agricultural Policy reform aid programs, crop limitations and investment subsidies). The model is multiperiodic to account for the investment decisions in irrigation equipment along a planning horizon, and farmers are assumed to be risk neutral and have perfect information about prices and water availability.

The objective function is:

$$\max \sum_{t=1}^{T} \text{EXC}_t / (1 + \text{ta})^{t-1} \qquad (1)$$

where EXC_t is the farm surplus in the year t; T is the planning horizon and ta is the rate of return.

Farm surplus is defined by the net present value of the farmers' profit flow over a time horizon of 20 years and can be written as:

$$
\begin{aligned}
\text{EXC}_t = & \sum_i \sum_k \sum_r X_{ikrt} \times (y_{ikrt} \times p_{it} + \text{subv}_{it}) \\
& - \sum_i \sum_k \sum_r X_{ikrt} \times \text{cp}_{ikrt} - \text{cf}_t - \text{CIRR}_t \\
& - \text{CLAB}_t + \text{PRECO}_t - \text{PRECO}_{t-1} \\
& \times (1 + tcp) - \sum_{t-E}^{t} \text{ann}_t + \text{CASH}_{t-1} \\
& - \text{CASH}_t - \text{CAP}_t \qquad (2)
\end{aligned}
$$

where subindex t accounts for time, i for crop type, k for soil quality and r for irrigation techniques. EXC_t is the farm surplus in year t; y_{ikrt} is crop yield; p_{it} is crop price; subv_{it} are product subsidies; cp_{ikrt} are production costs for each crop, soil type, irrigation method and year respectively; cf_t are fixed costs; CIRR_t are water application costs; CLAB_t are labor costs; PRECO_t is short term indebtedness; tcp is the short term interest rate; E is the long term loan maturity; ann_t is the long term loan instalment; CAP_t is capitalization (self funding for irrigation equipment investment) and CASH_t is cashflow.

The objective function is subjected to the following constraints (omitting other land, labor and financial constraints):

Investment restrictions in irrigation equipment:

$$\sum_i \sum_k X_{ikRt} \le \text{eqi}_{Rt} + \sum_{\substack{t-J \\ \forall t > J}}^{t} \text{INV}_{Rt}$$

$$R = 1, 2, \ldots, R \tag{3}$$

where R is the subset of irrigation techniques for which investment is required (sprinkler or drip irrigation); eqi_{Rt}: is the initial irrigation equipment used over a period of J years and INV_{Rt} accounts for investment in irrigation equipment.

Irrigation restrictions:

$$\sum_i \sum_k \sum_r (\text{nirr}_{ikr} \times X_{ikrt}) \le \sum_z \text{QAG}_{zt} \times \text{efd}_z \text{QAG}_{zt}$$

$$+ \text{QSOB}_{zt} = dot_z \times \text{sreg} \tag{4}$$

Where nirr_{ikr} are the crop water requirements; QAG_{zt} is water consumption z denoting type of water source; efd_z is a water distribution efficiency parameter QSOB_{zt} is water saved; dot_z is water allotment and sreg is the irrigated surface in the farm. Total water application costs (CIRR_t in the objective function) are composed of three elements: costs of water application in the farm including energy costs and irrigation equipment maintenance, fees paid by irrigators to the irrigation district and levies charged by the river basin agency. Of these three components, total water application costs (CAPL_t) are dependent on crop selection and are expressed as follows denoted by cexp_r water application costs, cman_t costs for irrigation equipment maintenance and cbom_t water pumping energy cost:

$$\text{CAPL}_t = \sum_i \sum_k \sum_r X_{ikrt} * (\text{cexp}_r * \text{nirr}_{ikr} + \text{cman}_r)$$

$$+ \sum_z \text{QAG}_{zt} * \text{cbom}_z \tag{5}$$

Fees paid by the irrigators to the irrigation district are not dependent on crop choice and are less determinant in simulating water pricing scenarios. The third water cost component, accounting for levies charged to the water authority in the river basin (CICH_t), can be expressed by the following equation:

$$\text{CICH}_t = \text{canon} \times \text{sreg} + \text{tar} \times \text{sreg}$$

$$+ \sum_z \text{QAG}_{zt} \times \text{pag}_z - \sum_z \text{QSOB}_{zt} \times \text{pbon}_z$$

$$\tag{6}$$

in which canon and tar are different fixed water levies per surface unit, pag_z is a variable volume charge and pbon_z is a price incentive for quantity of water saved.

2.2. Policy scenarios

The combination of the components of water application costs mentioned above, allows for the simulation of different pricing policy scenarios including incentive payments to the farmers wishing to adopt water saving strategies. These administered pricing scenarios represent different policy options with distinct government budget implications and farmers' income compensation schemes and are all intended to analyze water demand adjustments. Simulations are carried out along a wide range of simulation levels and pricing schemes are defined as follows:

Scheme 1 (V): Charge per volume applied (measured as t pta./m^3).

Scheme 2 (T): Block-rate charge defined by a set of prices (t pta/m^3) and quantities delivered (% of water allotment rights) such as follows: (i) t, 0–33%; (ii) t', 33–66% ($t'>t$); (iii) t'', 66–100% ($t''>t'$).

Scheme 3 (VB): Charge per volume applied plus a bonus paid to the farmer for the volume of water saved (measured by the quantity not consumed of his water allotment right) equivalent to 1.1 times the price charge.

Scheme 4 (BT): Block-rate charge plus a bonus paid to the farmer, defined by a charge per volume (t pta/m^3) levied only when quantities delivered are above 80% of the water allotment right and a bonus price paid to the farmer for any quantity of water saved below 80% of the water allotment right and equivalent to 0.9 times the price charge.

This wide range of situations taken into account in the empirical application of the model (i.e. ample variety of regions, river basins, water districts, representative farms and pricing schemes) has permitted to obtain a complete set of results that enables us to discuss, at national level, the implications of such water pricing policies in irrigated agriculture.

3. Results and discussion

Table 1 summarizes the aggregate results obtained with the model in each of the irrigation districts of the

Table 1
Effects of the application of water pricing schemes for different levels of water savings

Region	District	Income variation (%)				Governm. revenue (× 000 pts/ha)				Pr. Charge-Pr. bonus (pts/m³)			
		V	T	VB	BT	V	T	VB	BT	V	T	VB[a]	BT[bc]
10% reduction in water consumption													
CASTILLE	VILLORIA	−57	−42	−22	−17	125	83	39	14	34.6	23.2	12.7	37.5 (4.1)
	PARAMO	−57	−41	−29	−20	114	69	47	11	17.0	10.3	8.1	16.5 (1.8)
ANDALUCIA	GENIL CABRA	−14	−8	−8	−5	38	15	9	0	12.2	6.2	4.6	11.5 (1.3)
	VIAR	−3	−3	−1	−2	8	4	1	0	1.4	0.8	0.9	1.55 (0.2)
VALENCIA	ACEQUIA REAL	−69	−64	−35	−21	408	371	179	56	36	32.8	18.1	44.8 (6.7)
	NOVELDA	−32	−34	−28	−6	253	266	121	31	42	44.6	28.3	46.6 (5.2)
25% reduction in water consumption													
CASTILLE	VILLORIA	−61	−47	−26	−23	112	64	32	−7	37.3	21.3	16.8	−37.4[d]
	PARAMO	−67	−54	−32	−30	103	59	30	−8	18.3	10.6	8.5	−19.6[d]
ANDALUCIA	GENIL CABRA	−26	−31	−17	−10	48	37	8	−12	19	14.4	8.7	−18.6[d]
	VIAR	−5	−4	−2	−3	22	13	3	−2	4.4	2.5	2.2	−4.3[d]
VALENCIA	ACEQUIA REAL	−77	−74	−40	−32	348	318	107	0	37.2	33.8	19.1	−42.9[d]
	NOVELDA	—	—	−28	—	—	—	86	—	—	—	36.1	—
50% reduction in water consumption													
CASTILLE	VILLORIA	−66	—	−30	—	79	—	−5	—	39.5	—	22.0	—
	PARAMO	−77	−75	−37	−26	72	45	−3	−46	19.3	12.0	9.2	−20.5[d]
ANDALUCIA	GENIL CABRA	−31	−38	−21	−15	39	25	−10	−35	23.1	14.6	11.5	−23.2[d]
	VIAR	−16	−14	−8	−5	41	28	−7	−31	12.6	8.1	6.3	−13.8[d]
VALENCIA	ACEQUIA REAL	−91	−90	−48	—	252	233	−14	—	40.1	37	20.9	—
	NOVELDA	—	—	−34	—	—	—	−21	—	—	—	42	—

Price schemes: V: charge per m³; T: Block-rate charge; VB: charge per m³ with bonus; BT: Block-rate charge with bonus.
[a] Charge–bonus net price.
[b] Penalty price for surplus consumption.
[c] Effective price per m³.
[d] Bonus price.
[e] Bonus price.
Exchange rate: 125 PtAs/US$ (1996).

three regions considered and for the four different price schemes applied (two water districts per region, one modern and one old). Results are presented to show first, the farmers' response to the different policy scenarios, measured by the water demand response and the correspondent farmers' income variation, and secondly the role of the government measured by the price charge levied and/or the bonus price paid by the government agency to the farmer and the corresponding revenue collected. Results are presented for three different levels of water saving (10%, 25% and 50%).

3.1. Effects on water demand

When water demand schedules are calculated we can observe that differences in water demand in the three river basins become apparent as shown in the figures below (for price scheme 1 (V)). In fact, in the water districts of the Andalucia region (Fig. 1 and Fig. 4), water demand is elastic for price rates ranging from 4 to 30 pta/m^3 as in the districts of Castille (Fig. 2 and Fig. 5) demand is inelastic for low price rates and does not become price responsive until higher prices are attained (17 pta/m^3).[2] In turn, in the Valencia region (Fig. 3 and Fig. 6) demand is very inelastic even if the prices mount up to very high values (35 pta/m^3). Regional differences are clearly underlined following the similar results obtained in other countries (Moore et al., 1994).

The comparison between irrigation districts of the same river basin shows that water demand is less elastic in the modern water districts (Figs. 4–6; water districts of Genil–Cabra, Villoria and Novelda). Larger savings of water can thus be achieved in the older water districts (Figs. 1–3; water districts of Viar, Páramo and Acequia Real respectively) when the same price rate is being applied. This situation follows because the cost of increasing equipment efficiency in the older water districts is much lower than in the more modern districts. Technical endowments in the irrigation districts have a decisive influence in the capacity that different pricing schemes have to induce important reductions in water consumption. Old water districts have an ample margin for improving their
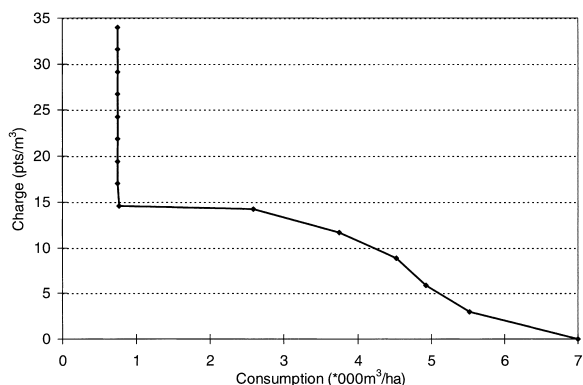

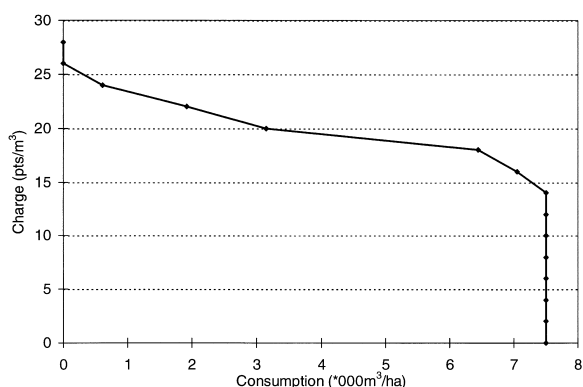Fig. 1. Old irrigation district: Viar (Andalucia).
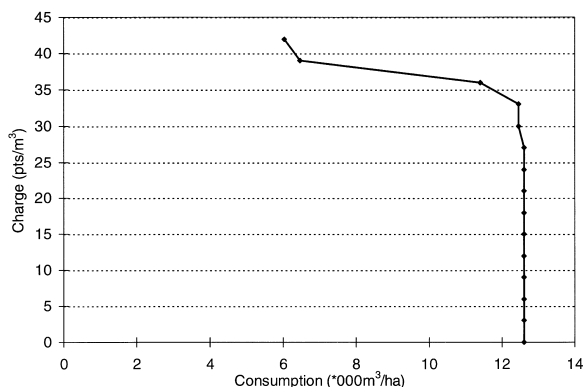

Fig. 2. Old irrigation district: Páramo (Castilla).

Fig. 3. Old irrigation district: Acequi Real (Valencia).

technical conditions and therefore for attaining large water saving levels (up to 2000–4000 m^3 ha). The modern water districts had already been endowed with

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[2]10 pta/m^3 is equivalent to approximately 8 cents of US$/m^3(1996).
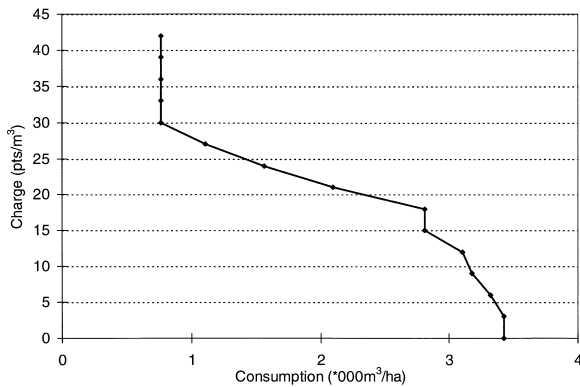
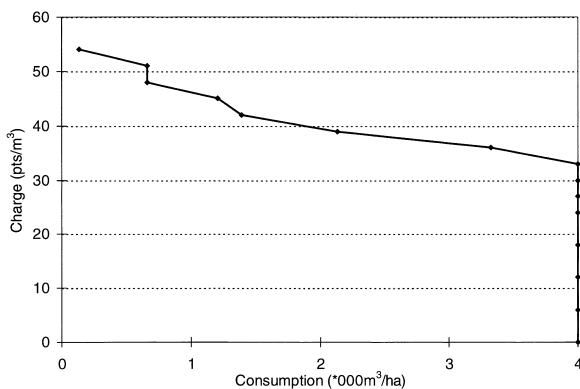Fig. 4. Modern irrigation district: Genil Cabra (Andalucia).

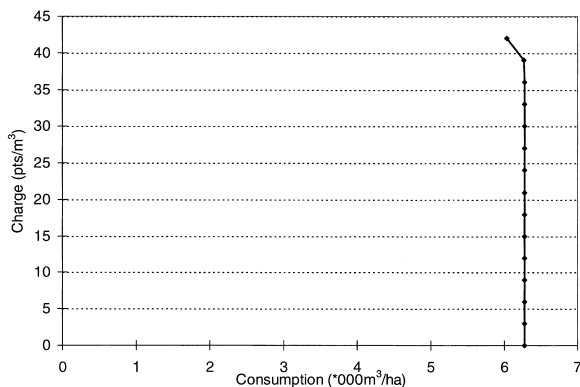Fig. 5. Modern irrigation district: Villoria (Castilla).

Fig. 6. Modern irrigation district: Novelda (Valencia).

more efficient irrigation systems and for this reason their response to price signals in water saving strategies is smaller.

3.2. Effects on farmers' income

The impact of pricing policies on farmers' income follows the similar regional specific pattern observed in the water demand response. Moreover, we can observe that different pricing policies produce in turn clear differential effects on the irrigation districts of our study. In fact to attain only a 10% reduction in water consumption when a uniform charge is applied, the irrigators of the Valencia region have to sacrifice up to 70% of their income, compared to 57% of their counterparts in the Castille region and a small 9% in Andalucia. However, when a bonus price is paid to the farmers to induce saving strategies, we can see that the Valencia irrigators loose 30% of their income and even half of this amount if bonus prices are paid together with levying block rate charges. The Castille irrigators follow the same trend as they loose a lesser amount of their incomes (25%) when they receive a bonus for the water saved and the andalusians a mere 4%, this region being less sensitive to the application of a price bonus than the other two. In Castille and Andalucia income decline is also smaller when block-rate charges are applied but less than in the Valencia region.

For higher levels of water reduction (25% and 50%) we can observe that income losses mount at a decreasing rate in all regions and therefore are proportionally higher for lower levels of water consumption, even more so if price incentives are included in the pricing policies. In fact, if water charges are applied without compensating the farmer for the water saved (within his water allotment) even small reductions in water consumption such as 5–10% will result in high income losses of more than 60% for all water districts in the regions of Castille and Valencia. This high income loss can be explained by agronomic and structural limitations. In the region of Castille of low productive potential, farmers are constrained to grow a very limited number of crops with restrained technical flexibility. Small reductions in water consumption appear only when water prices are high, yields are sharply reduced, dry farming may take place and farm income decreases. In the extremely productive Valencia, the small size vegetable and fruit tree farms limit crop changes. Farmers hold up to their profitable water consuming traditional crops until a gradual abandonment of the farming activity appears with the subse-

quent income loss, even for small reductions of water consumption that result from very high water prices.

3.3. Effects on government revenue

We can observe that regional differences in the revenue collected by the government agency tend to decrease as water saving increases. In fact, when only 10% of the water is saved, the revenue collected in Andalucia is small in average figures (23 000 pta. ha), much higher in Castille (120 000 pta. ha) and extremely high in Valencia (330 000 pta. ha). For higher levels of water reduction these differences are less dramatic (35 000; 105 000; 348 000 respectively for 25% reduction) (40 000; 75 000; 252 000, respectively, for 50% reduction). If pricing schemes with bonus are applied, government revenue decreases and regional impacts are reversed. Thus we can see that there is an inverse relationship across regions between water demand elasticity and revenue collected by the government. High water saving levels in Andalucia at low price rates account for low revenues collected by the water management agency. On the contrary, there is a direct relationship across regions between farmers' income loss and government revenue; highest income losses in Valencia concur with large revenues for the water management agency. In sum, we can argue that water saving and income loss are not symmetric in all water districts. In fact, only in Andalucia the negative income effects are smaller than the positive water saving effects for all pricing schemes, but this is reversed in the other two regions. These marked regional and structural differences for price-induced water saving have also been observed in the western states of the US (Moore et al., 1994).

3.4. Farmers' strategies

In all regions farmers respond to the new water policies with a modification of their farming strategies by growing less water demanding crops, substituting dry crops for previously irrigated crops and in some areas of frequent part-time farming by quitting all farming activities. For a given crop, few changes in technology (i.e. changes in irrigation technique, water management practices and cropping techniques) are observed in most districts because, for each crop there is an optimum combination of techniques and water

management that farmers will tend to choose given their structural conditions and agronomic restrictions of soil and clime (along the similar argument of Boggess et al., 1993). However, each region follows a particular trend and dominant strategies tend to be different across regions and water districts responding to the potential production activities. For low price rates, in the highly productive irrigation districts of the Andalucian region, the reduction in water consumption is due to the substitution of less water demanding crops, and for higher price rates irrigation decreases and dry farming appears. In the less fertile northern region of Castille the widespread dominant strategy for medium range price rates (when elastic demand intervals are reached) is the substitution of dry farming for irrigated farming as the Common Agricultural Policy aid programs increase the comparative advantage of dry farming for cereals and oilseeds. In fact, when prices reach reasonable levels (6–15 pta/m^3) dry farming will be more competitive in this less productive region and extensification will take place. In the extremely productive Valencia region, very small orchard farms and fruit tree plantations limit the farmers possibilities to change their high value added crops and they tend to abandon farming activity as a response to an increase in water prices (or slightly change to less water demanding orchard crops) rather than modify the established farming activities.

4. Conclusions

From the results obtained with the simulation model we can conclude that the differences in water demand observed in the three river basins can be explained by structural parameters which summarize the regional differences in farming flexibility (i.e. cropping systems, productive patterns and farm size). In fact, in the Andalucia region, the quick response of water demand to small price changes is due to its remarkable productive potential, crop variety and large farms. As opposed to the small family farms with very limited productive capacity and minor crop variety of the water districts in the Castille region and even more so to the highly productive, intensively irrigated and specialized orchard and fruit trees minifundia of the Valencian region. In turn, differences in technologies and water scarcity explain the intra-regional differ-

ences. Old water districts (Paramo in Castille, Viar in Andalucia and Acequia Real in Valencia) with higher water allotments are more elastic than modern districts (Villoria, Genil-Cabra and Novelda) with more severe water scarcity problems, low water allotments and higher technological efficiency in water conveyance.

Therefore, with respect to the water saving strategies, we can conclude that water pricing policies are regional specific. Within a reasonable price range (around 8–14 pta/m^3) desired levels of water savings will be attained (25%) in the water districts of the Andalucia region but the same policy will be ineffective in either the northern region of Castille or even less in the Mediterranean Valencia where water prices have to mount up to extreme values to induce slight reductions in water consumption with the subsequent negative effect on farm income. Thus the goals of water policies have to be carefully defined in these regions.

A comparative policy analysis leads to the conclusion that the different pricing schemes produce remarkably uniform effects across regions and water districts (i.e. the ranking of the effects produced by the various pricing schemes on water saving, income loss and government revenue, is maintained for all regions and districts). Therefore, comparing the different pricing policies we can conclude that bonus pricing induce the greatest amount of water savings and inflict less income losses to the farmers, although revenue collected by the water management agency is smaller. If no bonus is paid to the farmer, block-rate charges (scheme T) are more water saving than uniform charges per volume (scheme V). However, the magnitude of the differential effects induced by the pricing policies reveal intra-regional divergences. Pricing policy gaps are mild in the water districts of the Andalucia region, strong in Castille and very strong in Valencia.

In the regions of inelastic water demand, water policies have to be designed to include instruments in addition to pricing schemes if the desired goals of reducing water consumption are to be met. In fact, it has been analyzed that under certain structural and economic conditions the combined effect of pricing policies and water districts' modernization programs (i.e. programs that will increase conveyance efficiency at districts' level) can generate significant levels of water savings (Garrido et al., 1997).

Following the empirical results that show that water demand curves are more elastic in the old water districts (i.e. districts with low technical efficiency in the conveyance system) than in the modern water districts, we can conclude that pricing policies will be more effective to attain the desired levels of water savings in the former districts. Therefore, if the same water pricing policy is to be applied in a specific water basin or region, clear differential effects are to be expected. Certainly, for a given water pricing, while water savings could be achieved in the old water districts, it is likely that no reduction in water consumption will result in the modern districts and only farm income losses might take place.

Furthermore, high water prices (along the elastic interval of the water demand curves) could induce variations in the crop distribution that may cause policy conflicts in the application of the EU Common Agricultural Policy programs (e.g. reduction of the cultivated lands dedicated to cotton, sugar-beet and alfalfa and increase of the lands devoted to wheat, barley or sunflower surpassing the subsidized reference surface and incurring in the subsequent penalties).

The results of our model show that the adoption of irrigation technologies is not the most significant response to water pricing policies. While these results may indicate some discrepancies with other research conclusions (Caswell and Zilberman, 1985; Caswell et al., 1990), we have found that the adoption of water conservation technologies depends largely on structural factors, agronomic conditions and financial constraints and to a lesser extent on water prices. In fact, the results of our model are not inconsistent with reality. In fertile regions where high valued added crops are grown, water costs represent a very small proportion of the production costs and farmers choose the different technological sets (defined by a combination of crop and production technique) as a response to the changes in factors such as product prices, cost of labor services, crop yields, product quality characteristics, financial conditions and much less to changes in water prices. In sum, our results are consistent with reality in the sense that technology adoption in highly productive regions, can come about at zero water price rates. Therefore, this further seems to indicate that water prices do not change in a significant manner the cropping and technology strategies that farmers

choose according to their particular conditions. In old water districts of less productive regions, with high water allotments and limited crop diversification, technical change does appear and farmers adopt water conservation technologies as a response to an increase in water prices (e.g. changing from flood to sprinkler irrigation and improving water management and application). We can conclude that, in general, technological change does not appear to be unambiguously induced by water pricing policies and that other factors have to be taken into account to explain the farmers' selection of technological packages.

Choosing the appropriate water pricing policy will imply a careful definition of such policies in any given region or water district when the desired goal of water saving levels is to be attained. This research has tried to bring up some understandings to the difficult task that public authorities have to face in the design and implementation of water policies in the context of a growing scarcity of water resources and a mounting degradation of the water resource base.

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