A choice experiment of farmer's acceptance and adoption of irrigation water supply management policies

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Abstract

The efficient and sustainable use of water is becoming standard practice in water scarce regions and pro-active policy initiatives are taken to increase supply reliability considering the local context. The aim of this paper is to evaluate farmers' acceptance of policy strategies to increase water supply reliability in a water scarce river basin in the south east of Spain. Results from a choice experiment study suggest that farmers are willing to pay double water prices to ensure water supply reliability, through government supply guaranteed programs. However, they are averse to any other institutional changes that could assist the government to achieve increased water supply.

Keywords: irrigation water, Spain, choice experiment, water policy

1. Introduction

Efficient and sustainable use of water is one of the biggest challenges that policy makers all around the world face, especially in water scarce countries. Water pricing is usually seen as an economically efficient option to enhance the sustainability of water use (Turner et al., 2004; Dinar and Mody, 2004) as prices provide monetary incentives for users to save water. However, previous works showed that higher irrigation water pricing could endanger the competitiveness and the surrounding socio-economic conditions of extensively irrigated crops (Gomez-Limon and Berbel, 2000; Gomez Limon and Riesgo, 2004). Moreover, when crops are produced more intensively and are more profitable, such as horticultural or woody crops, the demand for water is more inelastic and the marginal price of water for these crops is considerably higher (Fernández-Zamudio et al., 2012).

Strategies ranging from supply augmentation to demand management have been advocated for better management of scarce water resources, and a number of policy instruments and economic incentives have been suggested for effective water management in agriculture (Tiwari and Dinar, 2002). In the Segura River Basin (SRB), located in the south-east of Spain, many important initiatives have been taken in order to solve the water scarcity problem in irrigated agriculture. From the stand point of supply, the most important inter-basin water transfer in Spain is the Tajo-Segura aquaduct. It was constructed during the 1970s providing a target amount of irrigation water of 400 million m3 per year. However, the real water transferred is variable depending on the availability of the water. In 2001, the National Hydrological Plan took into account a new inter-basin transfer from the Ebro River to Southeastern basins, by transferring 1,050 million m3 per year, with most of it intended for irrigated agriculture (MMA, 2001). The goverment changed in the Spanish General Election in March 2004 which ended the proposed transfers. However, the idea to build this transfer is still in the policy arena.

Also, important investments have been made in the SRB in order to improve wastewater quality and reuse. The current annual volume of treated wastewater in Murcia Region is equal to a sixth of the total renewable resources of the basin. Besides serving other purposes, treated wastewater currently supplies 12.8% of all irrigation water in the area. In both Spain and Europe, Murcia is a forerunner in the additional treatment and reuse of treated wastewater. It accounts for 27.64% of all reclaimed wastewater in Spain (Iglesias et al., 2010)

To supplement for insufficient and variable water allocation, farmers in the Basin use groundwater to make up for the shortfall in their supply. However, not all farmers have the right to pump groundwater and new rights to sink boreholes have not been issued since 1986. Hence, illegal pumping activities are common but undetected. Increased groundwater pumping has led to declining water levels. One option to slow down the decline of the water table is to have better management and control of groundwater resources. This can be done through prevention of illegal pumping activities and reassigning groundwater allocation rights to prevent further negative recharge.

In the SRB, there have been tentative steps towards water trading among irrigators in recent year but no formal water trading has occurred yet. The Spanish water law allows water markets in draught years and several transfers have occurred from irrigators in the Tajo River Basin to farmers in the SRB using the Tajo Segura channel. All the transaction has been carry out between ICs and supervised by the River Basin Authorities. Other trading options such as exchange centers or lease contract has been also carried out with little participation from farmers (Calatrava and Gómez-Ramos, 2009.) However, informal spot water trading can be found among farmers within the same IC.

Several studies demostrate that the adoption of DI, defined as irrigation supply below the full crop water requirements (English 1990), in the study area would be feasible (Egea et al., 2010) and profitable (Alcon et al. 2013). However, its use is not widespread because farmers do not know the technique and how it could work for their farms. Alcón et al. (2014) found that in the current economic climate where government spending is limited, policy makers can still promote the adoption of DI through means of scientific knowledge transfer using demonstration farms or farm test sites.

Rigby et al. (2010) examined uncertainty in water supply and the risk preferences of producers using a choice experiment survey. They analyzed, in the south east of Spain, how the choice of irrigation water allocations were affected by the levels of both guaranteed and uncertain water allocations. Farmers were prepared to pay a premium for increased water supply certainty, confirming that economic efficiency can be further enhanced. However, how supply certainty is achieved was not considered.

In this context, this paper aims to evaluate the adoption of supply and demand policy strategies used to improve water allocation across farmers, taking into account their specific demand for water and the institutional-economic context in which water is supplied. In order to control for the main water management characteristics, a choice experiment survey has been developed. The use of choice experiment surveys allows the researchers to explore whether farmers are willing to pay a premium for irrigation water and how several conjoint factors such as water supply guarantee and water delivery options are affecting this economic value. This study provides insights into how farmers value the attributes of irrigation water management by analysing individual choices of water delivery options.

Using a choice experiment approach to value irrigation water policies has the advantage of allowing the control of multiple dimensions of water policy simultaneously, such as water supply guarantee and other possible policy options that could assist the government to guarantee water supply.

2. Case study area

The irrigation communities (IC) selected for the case study are two economically most important and innovative in the study area, i.e. the Campo de Cartagena and Pantano de la Cierva (hereafter CCTIC and PDCIC respectively). The cropped areas are 41,325 ha and 1,946 ha, respectively. Both ICs use water from the Tajo transfer and the main crops are fruit and vegetables. These ICs have distribution networks based on pressure pipes, a computerized system for water conveyance and monitoring, hence the high water delivery efficiency achieved. Farmers have widely adopted drip irrigation in both irrigated areas.

Water price paid by farmers in the case study region, is among the highest in Spain (Alcon et al., 2010). The final price the farmer pays includes a series of levies to cover the investment, operational and maintenance costs of the own community. The average price paid by the farmers in the last 10 years varies between EUR 0.12/m3 and 0.24/m3. At the time of the data collection for this study the price paid by the farmers was EUR 0.16/m3 and 0.18/m3 for CCTIC and PDCIC, respectively. The average cost of groundwater extraction is around EUR 0.21/m3 but can reach up to EUR 0.74/m3 in extreme situations (MMA, 2007). While in PDCIC the boreholes are owned by the IC, in CCTIC groundwater is owned by farmers. A summary of the two ICs is provided in Table 1.

Table 1: Descriptive characteristics of the Campo de Cartagena and Pantano de la Cierva ICs

Characteristics (average values 2002-2010)	Campo de Cartagena-Cartagena	Pantano de la Cierva -Mula
Commanded area (ha)	41,325	1,946
Irrigated area (ha)	32,209.57	1,875.46
Annual irrigation water supply per unit irrigated area (m^3/ha)	1885	2771
Main system water delivery efficiency (%)	94.78	95.05
Groundwater use (%)	6.51	70.29
Distributions system	By turn	On demand
Effective Rainfall (mm)	121	132
Water price (€/m^3)	0.16	0.19
Storage capacity (m^3)	2,290,663	495,000
Drip use in 2010 (%)	96	93
Main crops	Vegetables and citrus fruit	Fruit and citrus fruit

Source: ICs managers

3. Methodology

3.1. The choice experiment

To explore how farmers respond to different water supply options and price changes, two attributes relating to water allocation and one water price attribute were presented (see Table 2 for list of attributes and attribute levels). The first attribute is related to a guaranteed level of water supply. In the current water allocation framework, farmers have no guarantee from the IC as to how much water they will receive each year. The amount of water received depends on their water entitlement and the amount of water (from the inter-state transfer program) that is available to the IC. However, the first attribute offers farmers the option to choose the preferred level of water that they would be guaranteed to receive each year (in m3/ha per year). The second attribute offers a number of policy measures that could be used to ensure water supply security in the future. These measures were identified by stakeholders in the area as the most prominent measures for managing water in the region. The cost attribute was defined as the price of water per cubic meter that farmers would have to pay in order to achieve a desired level of guaranteed water supply and water supply measure. The price of water in the design is between 25% and 200% higher than the current price, and is based on historical price levels recorded for this Basin.

Table 2. List of attributes and attribute levels of the choice set.

Attribute	Levels	Code
Amount of guaranteed water supply (m^3/ha per year)	No guarantee (SQ), 3000, 4000, 5000, 6000, 7000	GUARAN
Water supply measure	No new measure or action (SQ)	
	Water transferred from the Ebro River Basin	TRANS
	Increased access to good quality treated urban wastewater	RECLA
	Stricter control over groundwater abstraction	GROUND
	Water markets	MARKET
	The use of deficit irrigation	DI
Price (EURO per m^3)	No change (SQ), 0.18, 0.20, 0.24, 0.32, 0.36, 0.40	PRICE

The Ngene 1.0.2 software package (Rose et al., 2010) was used to generate an s-efficiency design that would help minimize the sample size required to estimate significant parameter values. An s-efficiency design was most suited for this study because the sample size is constrained by the limited number of farmers (population size). The priors were estimated from a pilot survey of the same study. The design consisted of 36 choice sets blocked by a factor of 9. Hence, each farmer sees four choice sets. This format is ideal for saving questionnaire completion time and preventing response fatigue (Bradley and Daly, 1994).

The hypothetical market scenario introduced before the choice sets described the current drought situation in the SRB and that currently a number of water management measures are under consideration including the guaranteed of water supply to the farmers each year. Farmers were asked to choose between two policy options and an opt-out option. An opt-out option refers to the status quo which is the current state of water supply in the basin i.e. there is no guaranteed level of water supply, water is sourced from the Tajo river basin, access to good quality treated urban wastewater and groundwater are limited, there are no water markets and the lower price of water is 0.16 EURO/m3. If the farmers choose Option A or B over the status quo, the price per cubic meter of water is higher than what they are currently paying but they would achieve a proposed level of guaranteed water supply and the government will apply a new measure for supplying the water. An example of a choice set is provided in Figure 1.

The following are proposed measures that will come along with an increase in the price of irrigation water. Which option do you prefer the most? Please consider your level of disposable income before answering this question.

	Option A	Option B	
Amount of guaranteed water supply (m^3/ha)	5,000	3,000	
Water supply measure	Stricter control over groundwater abstraction	Water markets	
Price of water that you would have to pay	0.36€/m^3	0.20€/m^3	
Which option do you prefer?	A	B	Neither

Figure 1. Example of a choice set

3.2. Statistical model

In the choice experiment questionnaire, each farmer is presented with a fixed set of options containing varying water supply levels, water supply measures and water prices and have to choose the option they most prefer. The most commonly applied method for modeling choices is the conditional logit model. A conditional logit model assumes that the utility for individual i from an alternative j is given by:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (1)$$

where ε_{ij} is a random term with an IID extreme value distribution (Train, 2003), and V_{ij} s the stochastic and deterministic elements of utility. In the linear case the latter can be extended to

$$V_{ij} = \beta_{ik} X_{ijk} \quad (2)$$

where X_{ijk} are the exogenous determinants of utility (potentially just the attributes, but possibly also attribute/individual characteristic interactions) and β_{ik} the marginal utilities.

The conditional logit model assumes that the parameters are homogenous across the population therefore can be restrictive in practice (Martin-Ortega et al. 2011). A mixed logit model, on the other hand, relaxes the assumption of independence of irrelevant alternatives that results from the independent and identically distributed property underlying the conditional logit model and allows for the parameters to be randomly distributed across the population (Ben-Akiva and Lerman, 1985) to capture preference heterogeneity.

The utility from choosing a particular option is determined by the characteristics of the attributes (in this case are guaranteed water supply level, water supply measures and water price) and individual specific characteristics. The functional form for the utility (V_{ij}) for individual i of alternative j is specified as:

$$V_{ij} = \beta_s SQ_j + \beta_g GUARAN_j + \beta_{pr} PRICE_j + \delta_t TRANS_j + \delta_r RECLA_j + \delta_g GROUND_j + \delta_m MARKET_j + \delta_d DI_j \quad (3)$$

where $\beta_s, \beta_{g,}, \beta_{pr}$ are the coefficients for the status quo (SQj), water supply level (GUARANj) and water price (PRICEj), respectively, and $\delta_t, \delta_{r,} \delta_g, \delta_{m,} \delta_d$ are the coefficients for each water supply measures.It is expected that WTP will increase with the level of guaranteed water supply. However, it is difficult to hypothesize which policy measure farmers prefer, if at all.

3.3. Survey implementation and data collection

The questionnaire consisted of three main sections. The first section contained questions relating to farm operations (e.g. farm area, type of crop grown, type of irrigation system used, and source of water used for irrigation) and the farmers' attitude towards the drought situation in SRB. The next section contained the choice sets and a follow up question to check for protest bids. The last section of the questionnaire consisted of socio-economic questions. The survey was conducted via face-to-face interviews in the farm IC offices during May – August 2012 on a random sample of 299 farmers in the CCTIC and PDCIC.

4. Results

An analysis of why respondents were not willing to participate in the choice experiment was carried out in order to identify protest answers from the sample. Three out of 183 farmers sampled in CCT IC chose the status quo in all the choice-sets shown. The number of protest bids in PDC IC was 13 out of 103. Therefore, we were left with 283 interviews with which to perform the analyses. Three models specifications have been developed (see Table 3). A simple conditional logit model containing only attributes in the choice experiment design is presented in Model 1 (Table 3).

Model 2 is a conditional logit model that contains interaction terms between the socio-economic variables and the status quo, the policy attributes or the price attribute. A number of interaction terms with socio-economic variables were tested but only farm location (whether the farm is in PDCIC or CCTIC), farm size and farmer's age were significantly affecting choice. A Likelihood Ratio test (LR) confirms that Model 2 performs better than Model 1 (LR = 332; $\chi^2_{0.05,8}$=15.51). In order to explore the functional form, a new model using random coefficients has been estimated. Model 3 has been estimated where the use of water price variables were randomized. Earlier iterations of the model had more randomized variables but non-significant ones were removed or were not randomized in the final model. The LR test rejects the null hypothesis of no significant differences in model performance (LR = 7.66; $\chi^2_{0.05,1}$=3.84) suggesting that the random coefficients specification in Model 3 is preferred.

The parameter value on the status quo variable suggests that farmers strongly prefer to move away from the current situation in which no water is guaranteed and water allocations are uncertain. The marginal utility of the attribute 'Amount of guaranteed water supply' was estimated by using dummy variables. Thus, the guarantee of 4000 m3/ha is most preferred by farmers, followed by the guarantee of 6000 m3/ha. This is counter intuitive but can be explained by crop mix and technology used by individual farmers. Farmers with citrus and fruit show higher preference for the attribute GUARAN4 (i.e. 4000 m3/ha) while horticultural and greenhouse farmers prefer higher amount of water guaranteed. However, all other policy options proposed to ensure guaranteed water supply are less preferred than the current policy, which is to have water transferred from the Tajo basin and groundwater. Thus, the only measure of comparison is to present the policy option in which farmers are least averse to. In this case, farmers are least averse to water transferred from the Ebro river basin, followed by the use of reclaimed water. The options of a higher control over groundwater sources, the adoption of DI and the use of water markets are significantly less preferred than the Ebro transfer and reclaimed water use but no significant differences have been found between these three measures (Wald test at 5% level). Thus, we found that options which require participatory efforts from farmers are less preferred.

Table 3: Conditional and mixed logit model estimates

	Model 1 (Cond. Logit)			Model 2 (Cond. Logit w/ interaction)			Model 3 (Random Parameter)		
	Coef.	S. E.	P>z	Coef.	S. E.	P>z	Coef.	S. E.	P>z
SQ	-2.63	0.27	0.00	-4.48	0.47	0.00	-4.76	0.53	0.00
GUARAN3	1.20	0.19	0.00	1.41	0.21	0.00	1.44	0.22	0.00
GUARAN4	1.53	0.19	0.00	1.91	0.22	0.00	1.93	0.23	0.00
GUARAN5	0.79	0.21	0.00	1.21	0.24	0.00	1.26	0.25	0.00
GUARAN6	1.38	0.25	0.00	1.88	0.28	0.00	1.93	0.29	0.00
GUARAN7	0.30	0.32	0.34	0.59	0.35	0.10	0.56	0.37	0.13
TRANS	-0.21	0.22	0.32	-0.98	0.29	0.00	-1.01	0.30	0.00
RECLA	-0.88	0.21	0.00	-1.23	0.28	0.00	-1.31	0.30	0.00
GROUND	-1.38	0.19	0.00	-2.12	0.26	0.00	-2.21	0.28	0.00
MARKET	-1.52	0.18	0.00	-1.79	0.23	0.00	-1.87	0.25	0.00
DI	-1.39	0.22	0.00	-2.14	0.28	0.00	-2.21	0.30	0.00
TRANS x PDC[a]				1.68	0.43	0.00	1.69	0.45	0.00
RECLA x PDC				0.36	0.49	0.46	0.35	0.51	0.50
GROUND x PDC				1.38	0.40	0.00	1.44	0.41	0.00
MARKET x PDC				-0.78	0.60	0.20	-0.71	0.61	0.25
DI x PDC				1.17	0.50	0.02	1.24	0.52	0.02
SQ x PDC				2.98	0.33	0.00	3.18	0.36	0.00
PRICE x Size[b]				0.04	0.01	0.00	0.04	0.01	0.00
SQ x Age[c]				0.02	0.01	0.02	0.02	0.01	0.06
PRICE	-10.41	0.63	0.00	-10.18	0.69	0.00	-11.05	0.82	0.00
Std. Dev.									
PRICE							2.65	0.61	0.00
Obs	283			283.00			283.00		
LL	-951.57			-785.43			-781.60		
LR chi2	584.11			916.40			7.67		
PseudoR2	0.23			0.37					

[a] PDC=Pantano de la Cierva IC; [b] Farm Size (ha); [c] Farmers age (years)

Farm location plays an important role in farmer choices. Farmers in CCT IC are more WTP to avoid the status quo than farmers from the PDCIC. In CCTIC average water allocation and rainfall are frequently lower than crop requirements, hence, the scarcer the water is in the area, the higher the propensity to change the current situation. Higher WTP could also be explained by the higher market value of the horticultural production in CCTIC.

Additionally, there are some preference differences for policy options between the two ICs. The Ebro water transfer option is more preferred for farmers in the PDCIC. Despite farmers in the ICs showing a negative utility for higher control over groundwater extraction, it is the community's second most preferred option. Stronger preferences for higher control over groundwater in the PDCIC and really low preference in CCTIC could be explained by the differences in property rights of groundwater between the two communities. In the CCTIC, groundwater is owned by farmers but in the PDCIC it is mainly owned by the IC, which could suggest that collective ownership avoids the individual free riding behaviour. The adoption of DI is more preferred in the PDCIC than in the CCTIC because DI is more suitable for fruit crops (Fereres and Soriano, 2007) and fruit crops are more prominent in PDCIC, while horticultural crops are more prominent in CCTIC.

Farmer characteristics also have an effect over preferences for current water management practices. The interaction term between age and the status quo 'Age * SQ' is positive and significant suggesting that older farmers are more averse to shifting away from the SQ, i.e. they are happy as they are.

Farm size affects the price coefficient. The sign of the coefficient of the variable Size x PRICE suggest that farmers with larger farms are less sensitive to higher water prices and hence are willing to pay more than small farms. This finding is in line with Rigby et al. (2010), who suggested that such preferences is explained by the economies of scale of bigger farms.

The coefficients estimated under the mixed logit model can be used to estimate the marginal willingness to pay (MWTP) for each one of the non-monetary attributes, or the maximum amount the respondent would be willing to pay or willing to accept to achieve a change in an attribute.

$$MWTP = -\beta_L/\beta_{pr} \quad (4)$$

where, for example, β_L is the coefficient of the guaranteed water supply attribute as specified in equation (3) and β_{pr} is the coefficient of the price variables. MWTP estimations can be found in Table 4.

Table 4. MWTP estimations for irrigation water (EURO/M^3)

	Mean	Std. Dev.		Mean	Std. Dev.
GUARAN3	0.14	0.02	TRANS	-0.04	0.00
GUARAN4	0.19	0.02	RECLA	-0.13	0.02
GUARAN5	0.12	0.01	GROUND	-0.17	0.02
GUARAN6	0.19	0.02	MARKET	-0.18	0.02
GUARAN7	0.05	0.01	DI	-0.17	0.02

WTP can be derived for each attribute using the parameter estimates. Assuming linear utility function of the attribute levels, and beyond the MWTP estimations, the WTP in the proposed water policy measures that could be used to ensure supply security in the future can be estimated comparing the marginal utility of the specific alternative to the status quo as specified in Equation (5):

$$WTP = -(\beta_{sq}+\beta_i)/\beta_p \quad (5)$$

where β_{sq} is the coefficient of the status quo, $\beta_p$is the coefficient of the price attribute and β_i is the coefficient of any of the attributes. Welfare change estimations for different levels of water guaranteed and policy measures can be found in Table 5 for model 3 specification.

Table 5. Welfare change estimations for irrigation water (EURO/m^3)

GUARAN	TRANS	RECLA	GROUND	MARKET	DI
3000	0.37	0.28	0.25	0.23	0.24
4000	0.42	0.33	0.30	0.28	0.29
5000	0.36	0.27	0.23	0.21	0.22
6000	0.42	0.33	0.30	0.28	0.29
7000	0.29	0.20	0.16	0.14	0.15

The welfare change estimates highlight the importance of securing water supply. Farmers are willing to pay to move away from the current situation of water supply uncertainty in order to have ensured water allocations. However, farmers paid more attention to the allocation levels of 4000 and 6000 m3/ha since they are more suited to different crop types.

In general, it is believed that farmers are averse to the introduction of any water policy changes unless they believe that the change would contribute towards their farming goals. This study finds support for this belief because farmers in both ICs stated that they would reduce their WTPs if there will be institutional (in this case policy) changes. According to Model 3, farmers are willing to pay approximately double the current price (EURO 0.32-0.46 /m3) for guaranteed water supply if the water still comes from the usual water source. When any institutional changes are considered, even when the water delivery method remains the same but the water source is different (i.e. shifting water transfer from the Tajo to the Ebro), WTP drops relative to the no policy action WTP level. The preference for using of reclaimed water in agriculture and the estimated WTP for this supply option is below the WTP for water transfers. It could be explained by the different perception about how safe its use is. In general farmers are willing to pay for wastewater treatment (Ndunda and Mungatana, 2013) but the perception of the effectively of the reuse is variable.

The policy option of stricter control over groundwater is more valued in the CCTIC than in the PDCIC. It is most likely because there is more competition for groundwater in CCTIC than in PDCIC Cierva. Farmers in the PDCIC are clearly averse to the use of water markets as indicated by the low WTP. The establishment of water markets receive very little support from farmers. In both ICs the WTP for these two measures is really close to the current water price being the less valuable policy measure by farmers. Welfare change estimations are below the price paid by farmers in the last 10 years. The welfare change associate with the adoption of DI technique translates to similar prices values to the current price of water at Campo de Cartagena IC in previous years. This result may indicate that farmers have a tendency to avoid adopting demand management measures.

5. Conclusions

Farmers in the SRB are interested in changing the current water supply uncertainty situation. They are willing to pay to secure irrigation water. However, the adoption of policy measures to ensure these allocations is seen as problematic because farmers show a high degree of aversion to institutional changes. Preferences are relatively homogeneous among farmers, bar the influence of age, and differences between ICs suggest that policy design should be focus for specific areas and not for specific farmer groups (i.e. grouping farmers by what type of crop they grow).

Despite not wanting to support any institutional changes, farmers are less averse to inter-basin water transfers and the use of reclaimed water, as compared to water markets and stricter control of over groundwater extraction. Thus, policy options that require a participative effort from farmers are less preferred in comparison to policies that government act on farmers' behalf. The preference for guaranteed water supply over the implementation of water conservation measures is an important finding because it indicates that an introduced conservation measure by the government may be met with resistance from farmers. However, the current environmental situation governed by climate change suggests that demand management is the best method for dealing with water scarcity. Hence, there is a disjunction between the right policy to implement and what farmers prefer to do and support.

In Spain, water is often used as a political tool when inter-regional water sharing conflict arises. To avoid these conflicts, water managers often seek institutional changes that would reduce water supply reliability from other regions. Despite the obvious need for such diversification seen by water managers, the users being the farmers still believe that inter-regional water transfer is the best supply option, following business as usual. Other institutional changes that could potentially increase water supply capacity within the region are less preferred. Fortunately, the increase use of reclaimed water is on the horizon but the discourse of where water supply is to come from still continues.

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