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Abstract

Irrigation water management is crucial for agricultural production and livelihood security in Morocco as in many other parts of the world. For the implementation of an effective water management knowledge about farmers' irrigation water demand is crucial to assess demand reactions of a water pricing policy, to establish a cost-benefit analysis of water supply investments or to determine the optimal water allocation between different users. Previously used econometric methods providing this information often have prohibitive data requirements. In this paper, the Contingent Valuation Method (CVM) is adjusted to derive a demand function for irrigation water along farmers' willingness to pay for one additional unit of surface water or groundwater. An application in the Middle Drâa Valley in Morocco shows that the method provides reasonable results in an environment with limited data availability. For analysing the censored survey data, the Least Absolute Deviation estimator was found to be a suitable alternative to the Tobit model when errors are heteroscedastic and non-normally distributed. The adjusted CVM to derive demand functions is especially attractive for water scarce countries where water management doubtlessly plays a decisive role.

Keywords: irrigation water; demand function; contingent valuation; marginal willingness to pay; least absolute deviation; Morocco
JEL-classification: Q15, Q21, Q25

1 Introduction

Irrigation water management is crucial for agricultural production and livelihood security in Morocco as in many other parts of the world. Implementing an effective water management system, however, is a complex task for policy makers. One important requirement for success is sufficient knowledge about farmers' demand or willingness to pay for irrigation water. This information is important for the adequate implementation of water pricing policies, for accurate cost-benefit analyses of investments in water supply or water market infrastructure, and also for determining an optimal distribution of the scarce resource between different users.

To obtain an estimate of a demand function for irrigation water, two principle approaches are used in the literature (BONTEMPS et al., 2001). Mathematical programming models are commonly used in developing countries as they do not require observations on functioning water markets. The value of irrigation water is implicitly derived from its simulated marginal value product in agricultural production (for a review of studies using mathematical programming models for the valuation of irrigation water (see for example CONRADIE and HOAG, 2004 or YOUNG, 2005). Alternatively, demand functions are estimated with econometric methods (examples are HUSSAIN and YOUNG, 1985; GRIFFIN and PERRY, 1985; OGG AND GOLLEHON, 1989; VEEMAN et al., 1997; FAUX AND PERRY, 1999; GRIMES and AITAKEN, 2008). Such studies, however, are less common in developing countries due to limited data availability.

Therefore, it is the aim of this study to discuss an alternative econometric approach for the derivation of a demand function for irrigation water for which the necessary information can be more easily obtained in a survey. This is achieved by applying the Contingent Valuation Method (CVM). The CVM is commonly used to value non-market environmental public goods or services. To the knowledge of the authors, the method has not been used to derive an entire demand function for irrigation water.

The proposed method is applied in a case study in the Middle Drâa Valley in southern Morocco. The Valley with its six oases is located between the Anti Atlas Mountains and the Sahara desert and is characterized by arid climatic conditions which make irrigation water essential for agricultural production. Irrigation water supply is characterized by periodic and human-controlled releases of surface water (SW) from a reservoir, in which SW inflows from the Upper Drâa Valley are collected. Declining water inflows due to droughts in recent years result in irregular releases from the reservoir forcing farmers to rely primarily on pumping groundwater (GW) from privately owned wells. As a consequence GW tables decline and water and soil salinization rates increase. These recent developments further increase the need for an effective management of the scarce resource.

The remainder of the paper is organized in the following way. Section 2 describes the application of the CVM in previous studies and the necessary adjustments of the CVM in order to derive a demand function for irrigation water in this paper. The field survey is presented in Chapter 2 together with the data analysis. Results are presented and validated in section 3 followed by conclusions.

2 Methods

2.1 Contingent Valuation Method applied to water resources

The CVM is a widely-used method to value environmental public goods or services. In the context of water research most contingent valuation studies concern household or drinking water uses (TIWARI, 1998). Nevertheless, there are several recent examples of studies applying the CVM in the context of irrigation water use (e.g. TIWARI, 1998; ABU MADI et al., 2003; BIROL et al., 2007; SHULTZ and

SOLIZ, 2007 or YOKWE, 2009). None of the studies, however, used the CVM to derive a demand function for irrigation water. In fact although these studies focus on irrigation water most of them value related goods, a specific program or services rather than irrigation water itself (e.g. SHULTZ and SOLIZ, 2007; BIROL et al., 2007 and TIWARI, 1998). The considered goods and services in these studies have in common that they can only be "consumed" in equal quantities by all consumers in contrast to irrigation water itself which is consumed in continuous quantities.[1] This difference matters because for the former it is straightforward to derive total demand at a given price from the contingent valuation results by multiplying the fixed quantity by the percentage of farmers willing to pay that price. For goods consumed in continuous quantities this approach based on a restricted choice is not suitable.

Only two of the studies mentioned above (ABU MADI et al., 2003 and YOKWE, 2009) focus on irrigation water itself. They determine an average value for one specific quantity but do not consider the relationship between WTP and consumption reflected in a demand function. However, just like the marginal productivity of irrigation water, WTP should be a decreasing function of consumption. Determining average WTP for several consumption quantities would work in principle, but is a rather undesirable procedure from a practical perspective. Alternatively, farmers' WTP to maintain their actual irrigation water consumption could be assessed. However, this is also a problematic approach because of potential strategic behaviour and likely low response rates due to the specific political discussion regarding water management in the region.[2]

Another more promising solution is to focus on farmers marginal WTP for additional irrigation water which is tested and discussed in this paper. Thus, a contingent valuation scenario was constructed asking farmers to imagine the opportunity to buy one (and only one) additional unit of water from a neighbouring farmer. This scenario is not only attractive because it circumvents the necessity to consider several quantities explicitly, but is also closer to farmers' reality since local exchange of water already takes place. It avoids mentioning the state or any other organisation as a provider of water, which might reduce potential strategic behaviour. Most importantly, however, focusing on farmers marginal WTP provides the opportunity to derive a demand function in a direct way. Therefore, it is important to recognize that in this set up the stated WTP amounts are equivalent to the shadow prices in a constraint optimisation model which are defined as far-

[1] A watershed restoration program to improve water quality (as in SHULTZ and SOLIZ (2007)) where the improvement is "consumed" in equal quantities by all farmers is a typical example.

[2] In contrast to most other river basins in Morocco the government hesitates to introduce a pricing scheme for irrigation water in the Drâa Valley because they fear considerable opposition among farmers LIEBELT (2003) . Therefore, water pricing is a particularly sensitive topic in the region.

mers' maximum WTP to loosen their water constraint by one unit (see TSUR et al., 2004). As is shown by TSUR et al. (2004) these shadow prices are themselves equivalent to the slope of the demand function at the specific water constraint. Hence, a regression explaining farmers WTP (in *DH/m³*)[3] by actual water consumption (in m³/ha) and additional explanatory variables can be estimated in which the coefficient of water consumption can be directly interpreted as the slope of a demand function. An entire function relating prices to irrigation water demand per hectare (of an average farmer), can be derived by calculation fitted values varying consumption quantity while keeping all other explanatory variables constant (at their means).

In order to distinguish between different kinds of irrigation water (GW and SW) as well as different points in time (summer season and winter season), four different contingent valuation scenarios were presented to each farmer (GW summer (GWS); GW winter (GWW); SW summer (SWS); SW winter (SWW).

For the valuation question the open-ended format was used. The question format is often criticized mostly because it is difficult to answer (e.g. ARROW et al., 1993, WHITEHEAD, 2006). MITCHELL and CARSON (1989) also acknowledges this point but argue that the question format works smoothly if respondents are familiar with the concept of paying for the good under consideration. As this is the case for irrigation water in the region (further discussed below) the open ended question format seems to be appropriate. Among others, the main advantage of an open-ended question format is that a direct measure of WTP is obtained which allows deriving a demand function in the way just described.

As recommended by the NOAA Panel (ARROW et al., 1993) an open-ended follow-up question is used for respondents who state a zero amount or refuse to answer the WTP question in order to determine the reasons for their answer. Additionally, the questionnaire also contains supplementary questions to guide respondents to the contingent valuation section and to derive additional explanatory variables required for the regression analysis. The selection of variables which potentially influence farmers WTP were based on previous studies, economic theory and knowledge about the situation in the region. In Table 1 the hypotheses as well as the corresponding variables are depicted.

[3] Rate of exchange to Euro(€): 1 Moroccan Dirham (DH) ~ 0.09 € (February 2009).

Table 1: Hypothesis about influences on farmers WTP and corresponding variables

Hypothesis	**Variables (*Variable name)***
(1) WTP for additional GW/SW decreases (increases) with increasing (decreasing) GW/SW consumption quantity.	- GW consumption; Measured as a monthly average in the last winter/summer season (*gwuse*) (in *m³/ha*) - SW consumption; Measured as a monthly average during the last year (*swuse*) (in *m³/ha*)
(2) Higher (lower) substitution possibilities between GW and SW decrease (increase) WTP for GW and *vice versa*.	- same variables as in (1) (i.e. *gwuse* in the SW scenario and *swuse* in the GW scenario)
(3) The more (less) profitable a farm operates the higher (lower) WTP.	- total date yield in the last year (*dateyield*) (in *kg*)[a] - total farm area (*area*) (in *ha*) *
(4) High (low) perception of declining water availability increases (decreases) WTP.	- wells a farmer possesses with water (*wellswater*) - wells a farmer possesses which dried out (*wellsdry*)
(5) A preference of SW (GW) over GW (SW) increase WTP for SW (GW).	- preferences of SW compared to GW (prefswgw)
(6) More (less) water intensive crops in the crop mix increases (decreases) WTP.	- water requirement calculated on the bases of the crop mix and optimal irrigation quantity (*requopt*) (in *m³/ha*) (date from ORMVAO, 1981)
(7) With increasing (decreasing) age of the respondents WTP decreases (increases).	- age of the responded (*age*)

[a] These rather crude measures of profitability are based on the assumption that profitability increases with farm size and date yield. They have obvious limitations but are the best approximation achievable in such a survey
[b] Selection of variables is in part based on findings of previous studies: ABU MADI et al., 2003; BIROL et al., 2007; SHULTZ and SOLIZ, 2007; TIWARI, 1998.

2.2 Field Survey

The field survey was conducted in October and November 2008 in the Middle Drâa Valley in Southern Morocco. Given the substantial heterogeneity between the six oases along the Drâa river and the limited resources available, it was decided to focus on one of the six oases. This decision enhanced the comparability within the sample and thus increases the workability and quality of the method. The chosen oasis Ternata is the largest oasis and located in the centre of the Valley and therefore takes also a middle position concerning water availability and water/soil salinization. After a pre-test (n=18), 95 farmers were interviewed in an in-person survey; 69 of these observation were usable, resulting in a response rate of 73%.

2.3 Data preparation

In the first step of the data analysis an investigation of invalid responses or protest bids which typically arise in contingent valuation studies is required. These cases are respondents who (1) refuse to answer the WTP question, (2) state a zero amount even though the good has a value to them or (3) give a invalid positive bid (an extremely high or low value) (HALSTEAD et al., 1992).

In particular valid zero responses have to be distinguished from the first two types of invalid responses. For this purpose, we used the follow up question given to respondents who giving no answer to the valuation question or stated a zero bid. Table 2 shows the answers for each contingent valuation scenario coded in different categories.

Table 2: Analysis of protest respondents

Scenario (%)	**GWW**	**GWS**	**SWW**	**SWS**
Would pay for water	47.8	68.1	47.8	55.1
Has sufficient water	29.0	10.1	10.1	2.9
Would give diesel for pumping	5.8	5.8	---	---
Percentage of valid responses	*∑ 82.6*	*∑ 84.1*	*∑ 58.0*	*∑ 58.0*
Would exchange water with other for free	1.4	1.4	2.9	2.9
Paying for water is a taboo	0.0	0.0	4.3	4.3
Question is not realistic	5.8	5.8	26.1	26.1
Did not cultivate his fields	7.2	7.2	7.2	7.2
Other reasons	2.9	1.4	1.4	1.4
Percentage of Protest response	*∑ 17.4*	*∑ 15.9*	*∑ 42.0*	*∑ 42.0*

All farmers who stated a positive bid or had sufficient water or – in case of GW – were willing to give diesel for their neighbours' motor pump were regarded as valid responses. Of these, the latter two were assumed to be valid "zero" responses.[4] All others who reject the contingent valuation scenario even though water actually has a value to them were assumed to be invalid responses. This is especially true for farmers who did not cultivate their fields in the last year because of water shortages.[5] From a theoretical perspective, these farmers should have a high WTP for one additional unit. In practice, however, one additional unit of water is worthless since it does not enable them to start production. Hence, these cases had to be excluded.

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[4] As discussed in section 2.4, in case of GW the censoring limit is assumed to be equal to the pumping cost for GW.

[5] During the survey some farmers were tilling land which was not cultivated in the last year because of recent rainfall and the hope of future availability of irrigation water.

Invalid positive bids of an extremely high or low value were detected using Box-Whisker-Plots for each of the four contingent valuation scenarios. From these it was decided to exclude observations lying more than three times the interquartile range away from the upper end of the box. This lead to one exclusion in each of the two SW scenarios and the GWW scenario as well as four exclusions in the GWS scenario.

2.4 Estimation

The contingent valuation results were analyzed by regressing the stated WTP amounts on a set of explanatory variables specified in Table 1. For the selection of an appropriate estimator it has to be recognized that the dependent variable is censored. For SW provided without costs to farmers, the censoring limit is equal to zero. Whereas for GW the censoring limit is equal to farmers' variable pumping costs, implying that even farmers with sufficient GW should still be willing to pay a price equal to variable pumping costs when having the opportunity to buy water from other farmers (the average variable pumping costs are assumed to be equal to 0.58 DH/m³ for the region as estimated by HEIDECKE and KUHN (2006)). Applying ordinary least squares in this case leads to inconsistent estimates. The Tobit model is a suitable alternative. The Tobit model with censoring limit c is represented by:

$$\begin{aligned} y_i^* &= x_i'\beta + \varepsilon_i, \qquad i = 1, 2, ..., N \\ y_i &= y_i^* \quad if \quad y_i^* > c \\ &= c \quad\ \ if \quad y_i^* \le c \end{aligned} \tag{1}$$

where y_i^* and y_i are the latent and observed variables of WTP respectively, β is a (*Kx1*) vector of unknown coefficients, ε_i are the error terms and x_i' is row vector of a set of K observed explanatory variables of observation i.

The four contingent valuation scenarios were analyzed in two separate models, one for SW and one for GW. In each model a dummy variable (*summer*; coded as 1 for the summer season and zero otherwise) was added to capture the seasonal effect. By introducing cross-terms between the summer dummy and all other variables it was also tested in a first step if the influence of one variable might differ between the two seasons. Using an *F*-Test the H_0-Hypothesis that all cross-terms were jointly equal to zero could not be rejected for both models. Consequently, no cross terms were considered in the following analysis. The set of explanatory variables included in the model was selected by estimating all model combinations of the variables given in Table 1 and selecting this model with the smallest Akaike's Information Criterion (AIC). The variables for GW and SW use (as well as a constant) were, however, always included in the model because they are the main variables of interest.

The standard maximum likelihood estimation of the Tobit model requires homoscedasticity and normality of the error distribution to obtain consistent estimates (VERBEEK, 2008). To test the hypothesis of homoscedasticity a Lagrange multiplier (LM) test proposed by GREENE (2008, pp. 876-877) was carried out. The normality assumption was tested using a LM test based on generalized residuals which was devised by CHESHER and IRISH (1987) and is also described in GREENE (2008, pp. 880-881). For the GW as well as for the SW model both tests clearly reject the assumption of normality (test statistics equal to 77.21 and 11.03 for SW and GW respectively[6]) and homoscedasticity (test statistics equal to 61.04 and 25.75 for SW and GW respectively[7]) of the error distribution at the 1% significance level.

An alternative in this situation is the Least Absolute Deviation (LAD) estimator proposed by POWELL (1984). Although the estimator is attractive because of its consistency under non-normal and heteroscedastic errors, it is rarely applied in the CVM literature (YOO et al. (2000) is one of the few exceptions). The major disadvantage of the LAD usually pointed out is its computational complexity, however, with today's computation power this was not found to be an obstacle. The LAD estimator was calculated using GAMS (General Algebraic Modelling System) and is algebraically represented by:

$$\min_{\beta} S_N(\beta) = \left(1/N\right)\sum_{i=1}^{N}\left|y_i - \max\left\{0, x_i'\beta\right\}\right| \qquad (2)$$

The set of explanatory variables in x_i' was selected using the same procedure as described above. Although POWELL (1984) derive a formula for asymptotic standard errors, YOO et al. (2000) argue that the bootstrap method is a more desirable method for small samples. They, however, use the bootstrap method to calculate standard errors and *t*-statistics for hypothesis testing. As KENNEDY (2008) points out, this procedure is problematic since critical *t*-values rely on asymptotic properties as well. Therefore, we use a bootstrap with 2000 replications and calculate the share of estimates lying above or below zero for each coefficient. This method allows calculating the P-values exploiting the empirical sampling distribution of the coefficient estimates.

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[6] The test statistic is chi-squared distributed with two degrees of freedom (GREENE (2008, p. 881)).

[7] The test statistic is chi-squared distributed with degrees of freedom equal the number of explanatory variables (GREENE (2008, p. 881)) (10 in the SW scenario and 6 in the GW scenario).

3 Results and Discussion

3.1 Descriptive results

The average farm size in the sample was 3.34 ha (median 2.68 ha). The average crop share consists of 52% wheat, 33% alfalfa, 10% barley, 4% vegetables and 1% maize. Date palms, the only cash crop in the region, are cultivated on 88% of respondents' area (on the same area as field crops). Because of an irregular supply of SW, farmers rely mostly on GW from their own wells. The average GW consumption in the sample was 358 m³/ha for a winter and 666 m³/ha for a summer months, while SW consumption was on annual average lower with 271 m³/ha per month.

Table 3: Descriptive results of dependent and explanatory variables

	N	Mean	Median	Std. Dev.	Min.	Max.
WTP for additional irrigation water (in DH/m³)						
GWW scenario	56[a]	1.03	0.88	0.51	0.58	2.94
GWS scenario	54[a]	1.33	1.18	0.57	0.58	2.94
SWW scenario	39[a]	2.09	1.65	1.75	0	5.51
SWS scenario	39[a]	3.65	2.75	3.30	0	13.77
Water use per month (in m³/ha)						
GW Winter	69	358.28	268.42	345.06	0	2 274.68
GW Summer	69	666.42	640.17	470.72	0	1 778.24
SW	69	271.09	233.81	187.37	0	605.33
Additional explanatory variables						
Date yield last year (in kg)	69	1 903.01	800	2 497.46	0	12 950
Number of wells with water	69	1.13	1	0.78	0	3
Number of wells without water	69	0.23	0	0.81	0	4
Optimal water requirement (in m³/ha/a)	69	6 103.7	6 165.06	2 718.23	0	13 036
Preferences of SW against GW[b]	69	2.48	3	0.83	1	3
Total agricultural area (in ha)	69	3.34	2.68	2.31	0.67	11.74
Age[c]	69	3.26	3	1.49	1	5

[a] *Only valid responses*
[b] *Coded as: 1 (SW is worse…), 2 (SW is equal…) and 3 (SW is better than GW)*
[c] *Age categories: 1 (18-29), 2 (30-39), 3 (40-49), 4 (50-59), and 5 (>60)*

Median WTP amounts for GW are equal to 0.88 DH/m³ and 1.18 DH/m³ for the winter and summer scenario, respectively. In comparison SW median WTP amounts are higher in the winter season (1.65 DH/m³) and in the summer season (2.75 DH/m³) which is plausible since GW availability is in general higher while the quality is lower and irrigation requires a higher labour input. It is also revealing to observe that the Inter Quartile Range (IQR) in both GW scenarios (0.60

DH/m³ and 0.88 DH/m³) as well as the variance (0.26 and 0.33) is substantially smaller than for the two SW scenarios (IQR: 1.93 DH/m³ and 4.13 DH/m³; Variance: 3.06 and 10.90). A reasonable explanation for this might be that farmers oriented their stated GW WTP amounts on known prices. As mentioned above, GW exchange between farmers is common in the region; 80.7% and 76.5% of the farmers reported that they have given GW to or received GW from others, respectively. However, in only 17.3% of the cases, farmers pay for that water whereas the rest only provides the diesel and use the motor pump and the water for free. The few farmers who paid for water (n=7) reported an average price of 1.20 DH/m³; asking farmers about the usual prices paid in the region revealed a comparable amount of 1.15 DH/m³ (n=34). Considering that it is most common in the region to exchange water for free and only pay for the diesel used for pumping it is likely that the few prices paid are also strongly oriented on total pumping costs (recalling that variable pumping costs were approximately equal to 0.58 DH/m³ HEIDECKE and KUHN (2006)). Comparing these prices to GW WTP shows strong similarities. It also explains the lower variance of the GW results compared to SW for which such an orientation does not exist[8].

It is also likely that this orientation made it easier for farmers to give an answer to the contingent valuation question. It explains why the item response rates to the GW scenarios is substantially higher than for SW (Table 2), even though almost the same scenario was used in both cases.

3.2 Estimation results

Table 4 summarizes the results of the LAD estimates for both the SW and the GW model. As pointed out by MITCHELL and CARSON (1989) it is possible from the regression results to assess the theoretical validity of the CVM findings, which they defined as "the degree to which the findings of the study are consistent with theoretical expectations". Using the derived hypothesis in Table 1 this can be done for the different models. In case of SW, the coefficients of all variables except one show the expected signs. Only the coefficient for the variable measuring water requirement show a negative sign which is not as expected. It is also apparent that most variables had a significant influence on WTP (i.e. three at the 5% level and four at the 10% level). Overall, the results indicate a high theoretical validity of the contingent valuation survey.

[8] If anything, only permanent water rights are traded for which prices do not provide an orientation.

Table 4: Results of the estimated LAD regression model

Dep. Variable	WTP for Surface Water (DH/m³) (n=78)		WTP for Groundwater (DH/m³) (n=110)	
Exp. Variables[a]	Coef.	Prob.	Coef.	Prob.
Constant	3.8487	0.0317	-0.4527	0.1646
Swuse	**-0.0048**	0.0428	0.0001	0.3335
Gwuse	-0.0002	0.2528	**-0.0001**	0.3692
Dateyield	0.0004	0.0670	---	---
Wellswater	-0.4352	0.1601	---	---
Wellsdry	1.0858	0.0982	0.1839	0.1037
Requopt	-0.0002	0.0614	0.0001	0.2781
Prefswgw	0.6467	0.1022	0.0901	0.1262
Area	---	---	---	---
Age	-0.5371	0.0594	0.0585	0.1684
Summer	1.5826	0.0222	0.4304	0.0433

[a] *Explanation of variables name given in Table 1.*

This observation is less clear for the GW models. Here, four out of seven variables show the expected signs (*swuse*, *prefswgw* and *age* were expected to have a negative influence). In the specification process three variables dropped out and from the remaining variables only the summer dummy was found to have a significant effect on WTP (at the 5% level). In contrast to SW, these findings clearly limit the theoretical validity of the results. In order to understand the different performance in two almost the same contingent valuation scenarios it is important to recall the relationship between GW WTP and pumping costs (as discussed above). The fact that GW WTP is oriented on pumping costs and does not exceed these costs implies that GW is not scarce for most of the farmers. Furthermore, when considering that WTP is oriented on costs which are independent of most of the explanatory variables used in the regression[9], the lack of significant influences on the dependent variable follows straightforwardly.

A further implication of the fact that the surveyed farmers valued the GW at the rather homogeneous access cost level, relates to the aim of deriving a demand function: The lack of variation of GW availability beyond what is currently voluntarily consumed at the given access cost restricts us to derive a demand function only for SW.

[9] In fact the only variable for which a relationship to costs is reasonable (and indeed found to be significant in the regression) is the dummy distinguishing between the summer and the winter season, since pumping costs strongly depend on the GW levels such that costs increase in the summer season.

3.3 Derived demand functions

To derive a demand function for an average farmer from the regression results expected values of WTP for varying consumption quantities have to be calculated while all other explanatory variables were kept constant at their means. For this the LAD estimates given in Table 4 are used. The resulting demand functions for the summer and winter season for the SW model are given in Fig. 1.

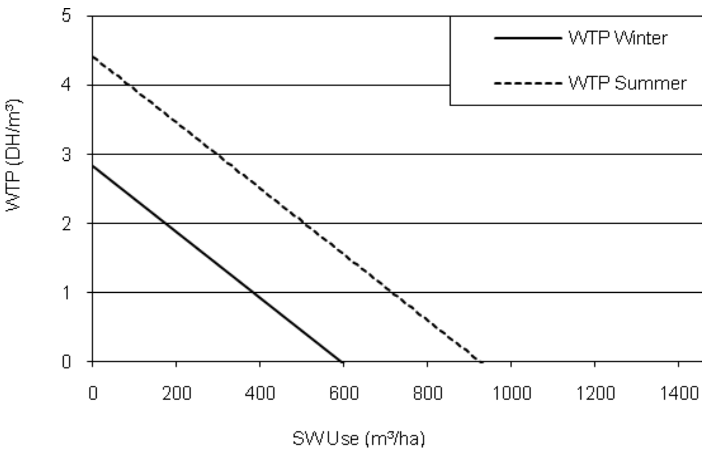

Fig. 1: Estimated demand functions for SW

The estimated demand functions for SW, given in Fig. 1, show a clear negative relationship between prices and demand. Demand sets in for prices below 2.8 DH/m³ and 4.4 DH/m³ for the winter and summer season, respectively. The slope of the demand function is equal to -0.0048 (the estimated coefficient of *swuse*). The demand function intersects the x-axes at a quantity of around 590 m³/ha and 920 m³/ha for the winter and summer season, respectively. At these points additional application of SW water did not further increase profits and hence shadow prices equal zero. When assuming that yield increases with additional water use but at a decreasing rate it is also clear that these points should be at or below the maximum yield. Using data for the optimal water requirement (i.e. optimal in the sense that water maximises crop yields not profits) per crop and month for the Drâa Region (ORMVAO, 1981) allows calculating an optimal water requirement for the average crop share of the sample for the summer season (average of May, June, July and August) and winter season (average of November, December, January and February). The calculated optimal requirement is equal to 622 m³/ha and 1303 m³/ha in the winter and summer season, respectively. This is, as expected, higher but comparable to the intersections of the demand function with the x-axes which are found at a quantity of 590 m³/ha and 920 m³/ha for the winter and summer season, respectively. It is, however, also important to consider the value range of the data on which the estimates are based which reaches for SW use only up to around 600 m³/ha making clear the that the estimated values for higher quantities have to be handled with care. Nevertheless, the findings generally support the validity of the derived SW demand functions.

Another way of validation is to compare the estimated demand function to functions derived in other studies. A SW demand function has been derived by TSUR et al. (2004) for the Rmel-Drader Perimeter in Loukkos, in the northwest of Morocco at the Atlantic coast. They use a Linear Programming approach and derive demand functions for three different farm sizes (small = 3.5 ha, medium = 15 ha and large = 150 ha). The differences of the agricultural production between the regions (i.e. smaller farms and more traditional production systems in the Drâa valley) need to be taken into account when comparing results. For comparison the demand function of small farms (3.5 ha) seems to be most appropriated since it is only slightly higher than the average farm size in the sample (3.42 ha). Although the information given in TSUR et al. (2004) does not allow an exact comparison it is nevertheless possible to compare characteristic points of the two functions. The zero point of the Loukkos demand function is equal to ~700 m³/ha for an average month[10] and hence lies in the middle of the two zero points of the estimated contingent valuation demand functions for surface water equal to 590 m³/ha and 920 m³/ha in the winter and the summer season, respectively. For consumption quantities down to ~200 m³/ha prices up to 4 DH/m³ are derived in the Loukkos demand function which is comparable to the estimated contingent valuation demand functions for surface water (at 200 m³/ha WTP is equal 1.9 DH/m³ and 3,5DH/m³ of the winter and summer season, respectively). Below a consumption of 200 m³/ha, however, prices in the Loukkos demand function jump abruptly up to 10 to 30 DH/m³ which is not found in the contingent valuation results but seems to be questionable amounts for the Drâa Region. Despite these differences for low consumption quantities the similarities between the two demand functions support the validity of the findings.

4 Conclusions

Knowledge about farmers demand for irrigation water is an important requirement to manage the scarce resource successfully. The proposed adjustment of the CVM provides a way to deliver this information to policy makers in a direct way. The crucial point of the adjustment is to derive the marginal WTP for one additional unit of irrigation water. This setup allows interpreting the stated WTP amounts as shadow prices. Together with information about farmers' water consumption,

[10] All values in TSUR et al. (2004) were rescaled to cubic meters per hectare and month.

these shadow prices can directly be used to estimate a demand function from the contingent valuation results.

The major advantage of the method is that the required data is relatively easily obtained in a survey even in the absence of observations on water market exchanges or other transactions. In order to apply the approach farmers should already consume the good under consideration and a substantial part of the farmers should face a water shortage (i.e. have a binding water constraint and a positive shadow price), making it suitable for all regions where water scarcity limits agricultural production. From a methodological point of view the only requirement is that the consumption quantities can be inquired in a survey. It is also helpful that farmers are familiar with the idea to pay for the good under consideration.

Through an application of the proposed method in the Middle Drâa Valley a demand function for SW were obtained whereas an estimation of a GW demand function was not possible. The obstacle to derive a GW demand function was the fact that despite recent trends of decreasing GW tables most farmers in the oasis still had sufficient GW. Consequently it was only possible to derive information about farmers current WTP but not about WTP if GW becomes scarce. For SW however, for which scarcity varies between farmers, the derived demand functions corresponded well to findings in other studies and additional information which supports the practicability of the method.

For an assessment of the validity of the findings it is important to keep in mind the relatively small sample size and the restricted research area. It also has to be pointed out that bookkeeping is hardly common in the region and traditional measures used by farmers are difficult to convert which reduce the accuracy of the findings.

Despite these limitations it was nevertheless possible to show that the method allows deriving an entire demand function with relatively little data requirements, making it particularly attractive for developing countries. For the Drâa Valley the approach can deliver important input if water pricing might be a policy option in future years or it can be used to derive different demand functions for the six oases which might provide crucial information for an optimal regional allocation of the resources.

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