Potential for Tradable Water Allocation and Rights in Jordan

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Abstract

This paper estimates the costs of buying water use rights from farmers located in the Mafraq-Azraq basin in Jordan. Farmers' water supply curve is estimated using data gathered from a contingent valuation survey. Estimation results indicate that a total supply of 29 million m^3 could be periodically purchased from farmers at an annual price of approximately JD 0.23/m^3 (1 JD ≈ 0.70 U.S. dollars), or a total cost of about JD 6.8 million per year.

Key words: Contingent valuation, non-parametric estimation, water supply curve.

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According to the World Health Organization (WHO) (2009), the problem of water scarcity on the planet is getting worse as cities and populations grow, and the demand for water increases in agriculture, industry and households. One of the regions most heavily affected by this problem is the dry Middle East. Most countries in the region are projected to be in a state of absolute water scarcity by 2025 which indicates that their annual water resources will not be sufficient to meet reasonable per capita water needs for their growing populations (Seckler, Molden and Barker, 1999).

Among the Middle Eastern countries, Jordan is one of the poorest in terms of its available water resources for domestic needs and food production (Salameh, 2000). Jordan's population-water resources equation for 2002 indicates that it is grossly out of balance, possessing about 306 m^3/capita compared to 1,700 m^3/capita needed to satisfy its municipal, industrial and agricultural needs (Haddadin, Salman and Karablieh, 2006). Moreover, it is estimated that by 2020 the per capita share of fresh water potential available for all purposes will fall to only 127 m^3/capita (Salman et al., 2006).

In 2005, the total supply of water in Jordan was 941 Mm^3 (Million m^3) coming primarily of surface water (251 Mm^3) and groundwater (496 Mm^3), with treated waste water being used on an increasing scale for irrigation (83 Mm^3). Accounting for all planned sustainable and non-sustainable sources of water over the next 15 years, it is projected that 1093 Mm^3 of total water will be available in 2020. However, the projected allocations to industry and municipalities are 118 Mm^3 less that their projected requirements.

Given the priority of households' basic water needs and the significant economic return from industry per cubic meter of water used, it is likely that the available water supply will be provided to these sectors first (Mohsen, 2007; USAID, 2007). However, little policy analysis has been conducted to date addressing the costs and benefits of transferring water from the agricultural sector to the industrial and domestic sectors. Most of the previous literature related to water use in the agricultural sector in Jordan has focused on water allocation within the sector toward higher valued crops or to increase the efficiency of irrigation water use (Doppler et al., 2002; Ramirez and Frank, 2010).

The Mafraq-Azraq aquifer accounts for a significant portion of the underground water resources available to Jordan (Bajjali and Al-Haddi, 2006). At present, most of the water extracted from the aquifer is devoted to irrigation through pumping previously sanctioned by the government. While the government has legal authority to rescind some or all of those pumping permits, farmers view them as long-term water rights. Because the aquifer is close to Amman, home to more than half of the country's population and two thirds of its economic activity, a major policy objective in regard to the Mafraq-Azraq basin is to examine the economic feasibility of water transfers from irrigation to urban water use to support Amman’s growth. An important part of this objective is to minimize economic impacts on farmers and the overall welfare of this region's inhabitants (Doppler et al., 2002). Therefore, the objectives of this paper are first to estimate the costs of buying water use rights from farmers located in the Mafraq-Azraq basin, and second to identify the factors driving farmers’ willingness to accept value to sell their water use rights. Assessing the value of that water to the agricultural sector will allow the government to fairly compensate farmers and ensure that rural communities are not economically damaged by an eventual water transfer. The results of this study will enable Jordanian policy makers to make more informed decisions on how to best meet future urban water demands in the country without hindering the economic welfare of agricultural producers and other rural inhabitants.

The first objective is accomplished by constructing the farmers' water supply curve. The supply curve is estimated using an innovative procedure that combines discrete and open ended contingent valuation (CV) questions and nonparametric methods. Previous studies using discrete contingent valuation questions and nonparametric procedures have focused on the estimation of the population willingness to pay function (*WTP*) (e.g., Day, 2007; Haab and McConnell, 1997). In this paper we show how these procedures can be modified when the primary object of concern of the CV study is the estimation of the supply curve using willingness to accept (*WTA*) data.

Methods and Procedures

Theoretical Framework

To conceptualize water use transfer rights, we consider a model of behavior that assumes that farmers who own a well are interested in maximizing their utility from the income earned from farming and/or other sources. The solution to this problem yields an indirect utility function

$$V(\mathbf{z},\mathbf{p},y) \qquad (1)$$

where **z** is a vector of measurable personal and farm characteristics and **p** is a price vector for the goods being consumed. The variable y denotes total income, which is assumed to be derived from two main sources, farm (π) and off-farm (*OFI*). A farmer's willingness to accept (*WTA*) to sell his/her water use rights is implicitly defined as:

$$V(\mathbf{z},\mathbf{p},y^0) = V(\mathbf{z},\mathbf{p},y^1 + WTA) \quad \text{or} \qquad (2)$$

$$V(\mathbf{z},\mathbf{p},\pi^0 + OFI) = V(\mathbf{z},\mathbf{p},\pi^1 + OFI + WTA) \qquad (3)$$

where the superscripts 0 and 1 in y and π^0 indicate the differences in income resulting from the reduction in farm productivity due to the loss of groundwater access. Hence $y^1 < y^0$ and $\pi^1 < \pi^0$, and, therefore, *WTA* is the minimum amount of money that the farmer is willing to accept in compensation for the income reduction.

Farmers' income from farming (π) can be represented as:

(4) $$\pi(p^q, \boldsymbol{c}; \mathbf{z}) = \{p^q q - \mathbf{c}'\mathbf{x}); (\mathbf{x}, q)\epsilon\tau\}$$

where p^q is output price, q is the output quantity , **c** is a vector of input costs, **x** is a vector of input quantities, **x** and τ is the production set. Hence, $WTA \geq \pi^0 - \pi^1$ which implies that *WTA* should be at least equal to the decrease in net revenue due to the yield reduction caused by the loss of access to groundwater for irrigation. Moreover, if production is not possible without irrigation, which is the case for most farmers in the Mafraq region, the net revenue reduction $\pi^0 - \pi^1$ equals π^0. Therefore, the *WTA* can be expressed as a function of the same factors affecting π:

(4) $$WTA = f(p^q, \boldsymbol{c}; \mathbf{z})$$

In summary, the results of the theoretical section indicate that farmers *WTA* for the water use rights should be influenced by the same factors that influence farm profitability: output and input prices as well as other factors affecting utility and the production function such as a farm and farmer characteristics.

Data

Data collection for this research took place in summer 2006, through a survey of 105 farmers in the Mafraq-Azraq basin. The survey sample was stratified by size to make sure that it was representative of the population of farmers in that region, which consists of approximately 300 producers. The survey instrument was administered by a team of three individuals from the local area with technical training in agriculture and strong ties with the local communities. Expert advice was sought to make sure that the questions were framed in a culturally acceptable way that was clear and understandable to the farmers while eliciting reliable responses. Two individuals who were also born and raised in Jordan's rural communities, held graduate degrees in agricultural fields, and had experience designing and conducting farmer surveys in that country were responsible to train the survey team and conducted a practice round of five interviews with them. The data and observational information gathered through these preliminary interviews were evaluated and used to refine the survey instrument and to formulate a culturally acceptable method to administer it. The survey contained about 50 questions and took an average of two hours to conduct.

Contingent Valuation Questions

The contingent valuation questions required to estimate the parameters of the *WTA* model used a dichotomous choice format, where a farmer was asked to identify his choice to accept or not to accept to sell their water use rights at a stated price. Surveyed individuals were initially asked if they would accept to sell their water use rights at some initial P_I. If they indicated that they were willing to accept the initial bid, they were subsequently asked if they would be willing to accept a lower bid (P_{SL}). Alternatively, if farmers were not willing to accept the initial bid, a higher bid (P_{SH}) was offered to them.

The four possible responses to the bid scenarios are (1) a "yes" to both bids, (2), a "no" followed by a "yes", (3) a "yes" followed by a "no", and (4) "no" to both bids. The sequence of questions defines the following ranges for the true *WTA* values: $(0,P_{SL}]$, $(P_I,P_{SH}]$, $(P_{SL},P_I]$, and $(P_{SH,}\infty)$. The following four discrete outcomes of the bidding process are observable:

(5)
$$D = \begin{cases} 0 < WTA \leq P_{SL} & (response\ outcome\ 1) \\ P_I < WTA \leq P_{SH} & (response\ outcome\ 2) \\ P_{SL} < WTA \leq P_I & (response\ outcome\ 3) \\ P_{SH} < WTA < \infty & (response\ outcome\ 4). \end{cases}$$

The initial bids (P_I's) used in the survey included 0.067JD/m3, 0.133JD/m3 and 0.200JD/m3 (1JD≈1.5$US). Lower and higher subsequent bids were calculated subtracting or adding 0.033JD to the initial bids. In addition to the four outcomes shown in (5), all the farmers that answer "no" to both bids voluntarily provided their minimum willingness to accept value in an open ended format. As we will discuss in the next section, this information proves useful for modeling purposes. We believe that since the open ended answers were willingly provided by the survey respondents who are used to the practice of bargaining still prevalent in the region, the procedure is less likely to suffer from the criticisms mentioned by the NOAA panel (Arrow et al., 1993) when individuals are asked directly their *WTP* or *WTA*: 1) lack of realism since the procedure is not commonplace in a person daily routine, and 2) incentive to overestimate the *WTA* or *WTP* values.

Econometric Models

WTA model

Estimation of the parameters of the *WTA* model was carried out using the nonparametric approach for interval-censored data proposed in Turnbull (1976). This estimation technique does not impose ad hoc assumptions on the distribution of *WTA, F(WTA).* Denoting the lower bounds of the intervals in (10) as P_L and the upper bounds as P_H, the probability of observing an individual *i* from this population indicating that his *WTA* lays in the interval between P_{L_i} and P_{H_i} is given by (Day, 2007; Turnbull, 1976):

(6) $$P\left(P_{L_i} < WTA_i \leq P_{H_i}\right) = F\left(P_{H_i}\right) - F(P_{L_i}) \qquad i = 1,2, \ldots. N.$$

The probability of observing a particular set of responses in a random sample of N individuals from the population of interest is given by the likelihood function:

(7) $$L = \prod_{i=1}^{n} F\left(P_{H_i}\right) - F(P_{L_i})$$

In a contingent valuation survey, the bid amounts used in the dichotomous questions are specified by the researcher. Assuming that *WTA* is non-negative, each of the pre-specified bid amounts can be denoted such that:

(8) $$0 = B_0 < B_1 < B_2 < \cdots < B_M < B_{M+1} \leq \infty.$$

The amounts in the bid design also form a series of m intervals of the form $(B_{m-1}, B_m], m = 1 \ldots M$, which are usually referred to as basic intervals to differentiate them from the individuals' *WTA* intervals defined in (5). In order to express the likelihood function in terms of the basic intervals we define an indicator variable d_{im} which indicates whether an individual's *WTA* interval includes the m^{th} basic interval.

(9) $$d_{im} = \begin{cases} 1 & if\ P_{L_i} < B_{m-1},\ B_m \leq P_{H_i} \\ 0 & otherwise \end{cases},\ m = 1, \ldots, M+1; i = 1, \ldots, N$$

Using this indicator variable, the likelihood function corresponding to (7), and simplifying notation such that $F(B_m) = F_m,$ the resulting log-likelihood function is:

(10) $$\ln L = \sum_{i=1}^{N} ln \sum_{m=1}^{M+1} d_{im}[F_m - F_{m-1}].$$

Given that the probability distribution of the *WTA, F(WTA)* is unknown, Turnbulls' procedure considers each F_m as a parameter to be estimated. Moreover, in order to ensure that the estimates of the likelihood define a valid cumulative distribution function, the problem needs to be expressed as a constrained maximization problem of the form:

(11) $$Max_{\boldsymbol{F}} \ln L(\boldsymbol{F}|\boldsymbol{d}) = \sum_{i=1}^{N} ln \sum_{m=1}^{M+1} d_{im}(F_m - F_{m-1})$$

Subject to: $0 = F_0 \leq F_1 \ldots \leq F_{M+1} = 1$

Since (11) is strictly concave, the F_m estimates of are unique. Estimation can be then carried out using Turnbull's self-consistent algorithm (Day, 2007; Gomez, Calle and Oller, 2004; Turnbull, 1976).

Supply of Water from Agricultural Uses

In contrast to traditional contingent valuation studies in the environmental economics literature where the main outcome of interest is the population mean willingness to pay (*WTP*) value, the construction of the supply curve requires estimates of the individuals' *WTA* values (e.g., Haab and McConnell, 1997; Dorfman et al., 2008). In this section we outline a procedure which allows estimation of farmers' unobservable *WTA* amounts using the estimated F_m parameters. First notice that an estimate of the probability that the *WTA* of farmer *i* is in the basic bid interval *m* conditional on belonging to the *WTA* interval $\delta_{im} = P\left(WTA_i \in (B_{m-1}, B_m] \mid P_{L_i} < WTA_i \le P_{H_i}\right)$ is given by (Day, 2007; Fay and Shih, 1998):

(12) $$\delta_{im} = \frac{d_{im}(F_m - F_{m-1})}{\sum_{j=1}^{M+1} d_{ij}(F_j - F_{j-1})}$$

The expected *WTA* can be written as (Carlson et al., 1994; Haab and McConnell, 1997):

(13) $$E(WTA) = \int_0^{B_{M+1}} WTA\, dF(WTA) = \sum_{j=1}^{M+1} \int_{B_{j-1}}^{B_j} WTA\, dF(WTA).$$

Replacing *WTA* by the lower or upper bound of each interval, it can be shown that the lower (LB) and upper bound (UB) estimates of the expected *E*(*WTA)* are:

(14) $$E(WTA_{LB}) = \sum_{j=1}^{M+1} B_{j-1}(F_{j-1} - F_j)$$

(15) $$E(WTA_{UB}) = \sum_{j=1}^{M+1} B_j\,(F_{j-1} - F_j).$$

Therefore, lower and upper bound estimates willingness to pay for farmer *i* are:[1]

(16) $$E(WTA_{LBi} | P_{L_i} < WTA_i \leq P_{H_i}) = \sum_{j=1}^{M+1} B_{j-1}\,\delta_{ij}.$$

(17) $$E(WTA_{UBi} | P_{L_i} < WTA_i \leq P_{H_i}) = \sum_{j=1}^{M+1} B_j\,\delta_{ij}.$$

Since the calculation of the upper bounds in (15) and (17), require an estimate of B_{M+1}, this value was estimated using the willingness to accept values provided by those farmers' that answered "no" to both bids. As shown in Cooke (1979), an estimate of the upper bound of a random variable is given by $2Y_n - Y_{n-1}$ where Y_n and Y_{n-1} are the nth and nth-1 order statistics based on the original sample. Hence, the highest two *WTA* values provided by the group of farmers in response outcome 4 (equation 5) were used for the calculations.

Supply Curve Estimation

A supply curve can be created using a function $\rho_j(op)$ such that (Dorfman et al., 2008):

(18) $$\rho_j(op) = \begin{cases} 1 & \text{if } \widehat{WTA}_i > op \\ 0 & \text{otherwise} \end{cases}$$

where $\widehat{WTA}_i$ is given by (14) or (15), and *op* is the offered price. Then the supply curve can be written as:

(19) $$A(op) = s \sum_i W_i \rho_i(op),$$

[1]Even though we refer to these estimates as the farmers' *i WTA* values, they represent the *WTA* values for all the individuals sharing the same initial bid value and the responses to that and the subsequent bid (i.e., individuals sharing the same set of d_{im} and δ_{im} values). Hence, the resulting supply curve is a step function.

where W_i is the amount of water currently used by farmer i, and s is the inverse of the proportion of farmers in the population being represented by each sampled individual. Conservative and liberal estimates of the water supply curve $A(op)$ can be calculated by using the WTA estimates presented in (14) and (15), respectively.

Determinants of WTA

In order to analyze the effect of several economic variables and farm and farmer characteristics on farmers' *WTA* value we assumed the following *WTA* function:

(20) $$WTA = X\beta + u$$

where X is a vector of explanatory variables, β is a conformable vector of coefficients and u is a random variable accounting for unobservable characteristics. By using equation (18) and assuming that $\sim H(0, \sigma^2)$, where H is a cumulative distribution function with mean zero and variance σ^2, then the choice probabilities corresponding to expression (5) are:

(20.1) $$P(WTA \leq P_{SL}) = H(P_{SL} - X\beta)$$

(20.2) $$P(P_I < WTA \leq P_{SH}) = H(P_{SH} - X\beta) - H(P_I - X\beta)$$

(20.3) $$P(P_{SL} < WTA \leq P_I) = H(P_{SL} - X\beta) - H(P_I - X\beta)$$

(20.4) $$P(P_{SH} \leq WTA) = 1 - H(P_{SH} - X\beta)$$

and the log-likelihood becomes:

(20.5)

$$L = \sum_{D_1} ln\, H(P_L - X\beta) + \sum_{D_2} ln[H(P_H - X\beta) - H(P_I - X\beta)]$$
$$+ \sum_{D_3} ln[H(P_L - X\beta) - H(P_I - X\beta)] + \sum_{D_4} ln\, [1 - H(P_H - X\beta)]$$

where D_j indicates the group of individuals belonging to the *j*th bidding process outcome. Given a choice for the cumulative distribution function *H*, the parameters β and σ^2 can be estimated. Notice that in contrast to supply estimation where nonparametric methods were used, parametric procedures are applied in this case since, to the best of our knowledge, nonparametric regression models for interval censored data are not available and semi-parametric methods are only recently being developed (Gomez, Calle and Oller, 2004; Yu and Wong, 2003). The approach outlined in equation (20) is an adaptation of the censored regression procedure for the estimation based on “closed-ended” contingent valuation survey data proposed by Cameron and James (1987) and Cameron (1988) for the case when participants respond in a dichotomous fashion (yes/no) to a single bid. Specifically, for the purposes of this study, their procedure is adapted to account for the double bidding process and the four resulting outcomes summarized in expression 5. In addition, in order to use the additional information contained in the open ended responses from farmers’ answering no to both bids, the log-likelihood in (20.5) is modified as follows:

(20.6)
$$L = \sum_{D_1} ln\, H(P_L - X\beta) + \sum_{D_2} ln[H(P_H - X\beta) - H(P_I - X\beta)]$$
$$\sum_{D_3} ln[H(P_L - X\beta) - H(P_I - X\beta)] + \sum_{D_4} ln\;\; h(WTA - X\beta)]$$

where *h* is the probability density function corresponding to *H* and *WTA* is the open ended value provided by farmers.

Estimation of the parameters in equations (20.5) and (20.6) require assuming a specific distributional form for *H*. The most commonly assumed distributions are the lognormal and the normal (e.g., Cameron, 1988). The model was estimated under both distributions to test for sensitivity of the results to the distributional assumption. The vector of explanatory variables in (20) included the average price of the products sold in the farm, the cost of water use and several characteristics of the individual producers and their farm operations (see Table 1). Maximization of the log-likelihood functions was performed using MATLAB.

Results and Discussion

Summary statistics are presented in Table 1. Sixty three percent of respondents indicated that farming is their main source of income, however, only 37% of farmers actually live in the farm. Respondents were 51 years of age on average and 31% had technical or university education. To ascertain farmers' knowledge about the groundwater depletion, we asked whether they knew if the water table was dropping. Seventy seven percent of farmers indicated that they knew that it was. Eighty two percent of farmers interviewed own the well used for irrigation, whereas the remaining 18% percent rent it. The average price per unit of water paid by farmers renting the wells is highly variable with an average of JD 0.18/m^3, a standard error of JD 0.04/m^3 and a maximum value of JD 0.93/m^3. The few cases with very high unit costs (>JD 0.25/m^3), were farmers who bear the fixed cost of renting a well but did not use much water to grow crops that year. Some variability was observed on the total well rental prices also, likely to be due to differences in maximum pumping capacity, demand for water near the well's location, etc.

On average farmers pumped about 140,000 m^3 (0.14 Mm^3) per year. Since the sample of producers surveyed represents approximately one third of the region's farmers population, it is estimated that more than 42Mm^3 of water are extracted from the aquifer for agricultural use each year, which is well above its safe yield estimated at 34Mm^3 (Salameh and Haddadin, 2006). The average total cost of pumping water from the aquifer is JD 0.3027/ m^3. This includes energy costs (76%), government payments (1%), well maintenance (12%) and well rental expenses

(11%). Regarding the government payments, it should be noticed that after the enactment of Jordans' Groundwater bylaw No. 85 of 2002, farmers extracting more that 0.15 Mm^3 per year are supposed to pay a government fee (Venot and Molle, 2008). However, the survey results indicate that only 11 out of 40 farmers pumping more than 0.15 Mm^3 of water had pay any government fee, which highlights the difficulties in enforcing water regulations in that country (Venot and Molle, 2008).

Summary statistics of the respondents to the double bounded dichotomous choice questions are reported in Table 2. Only 20% of the farmers indicated they would sell their water property rights at the initial bid price. On the other hand, a combined 60% of farmers answered YES to the follow-up questions. The average bid in the first dichotomous choice question for farmers that responded YES was JD 0.16 versus JD 0.13 for those respondents that answered NO. Average bid prices in the second choice question were JD 0.03 lower or higher depending on farmers' response to the first bid.

Table 3 reports the F_m parameter estimates as well as the upper (JD 0.39/m^3) and lower (JD 0.15/m^3) bound estimates of the population mean *WTA*. Interestingly, for the 18% of the farmers who rented wells, the average lease charge was JD 0.18 per m^3 of water yield, which means that most well owners (82%) value the water they pump for agricultural use at more than JD 0.18 per m^3 of water. Therefore, the average lease charge of JD 0.18 per m^3 could be considered a reasonable lower-end estimate of the intrinsic value of water in this region. Note that this figure is very close to the model's lower-bound estimate of JD 0.15/m^3. The mid-range WTA of JD 0.275/m^3 seems generally realistic since other survey data indicates that the average agricultural sale revenues for all 105 farmers in the survey are JD 0.96/m^3 and the average cost of pumping water stands at JD 0.27/m^3. Therefore, the remaining JD 0.69 /m^3 of revenue would have to cover all other variable costs and pay for the profits generated as a result of having access to the water for agricultural production. In the case of well renters, on average, those profits are reduced by JD 0.18/ m^3.

Unique estimates of the population mean *WTA* can only be obtained by assuming a specific probability distribution for *WTA*. However, lower and upper bounds can be established on the basis of the non-parametric model without having to make such assumption (Figure1). The "water prices" in the vertical axis are the farmers' estimated *WTA* values. Hence, the supply curve indicates the total amount of water that could be purchased from farmers at different water prices and can be used to predict the amount of funding required to purchase various water quantities. Interestingly, the predictions are very precise (i.e. the lower and upper bounds are very close to each other) up to a total supply of 29 Mm^3, and the model suggests that this amount could be periodically purchased at an annual price of approximately JD 0.23/m^3, or a total cost of about JD 6.8 million per year. For a permanent buyout, at a real discount rate of 5%, these amount to present values of JD 4.6/m^3 and JD 136 million over an infinite time horizon.

This total amount could be lower if the government was able to price discriminate by, for example, seeking long-term buyout contracts at increasing unit prices over time. Specifically, the estimated supply curve suggests that 14 Mm^3 could be auction-purchased during the first year at an annual price of about 0.10 JD/m^3 (permanent purchase price of JD 2.0/m^3, permanent purchase cost of JD 28 million). Another 8 Mm^3 could be secured in the future at an average annual price of JD 0.17/m^3 (permanent price of JD 3.4/m^3, cost of JD 27.2 million). Purchasing an additional 7 Mm^3 is estimated to cost approximately JD 0.23/m^3 (permanent price of JD 4.6/m^3, cost of JD 32.2 million).

In short, price discrimination over time could save the government about JD 49 million while fairly compensating the farmers for what the water is worth to them. Purchasing water in excess of 29 Mm^3 per year might prove substantially more expensive. This significant uptick in the supply curve at approximately 2/3rd of total annual extraction coincides with the fact that, according to the survey, about 30% of the water is used by farmers with gross sale revenues in excess of JD 1.0/m^3, and 12.5% is applied by producers with revenues of over JD 2.0/m^3. Likely, water is much more valuable to them than for the remaining farmers whose sale revenues only average JD 0.40 /m^3.

Another advantage of price discrimination is that the farmers for whom the water has more value would not sell it at the lower offer prices, and these are likely the ones who produce the most economic impact in the region. Specifically, the 20% of the farmers with sales revenues in excess of JD 2.0/m^3 apply 12.5% of the water but generate 48% of the revenue, and the 39% of the producers with revenues of over JD 1.0/m^3 use 30% of the water but generate nearly 75% of the total revenues from the sale of agricultural products in the Mafraq-Azraq region. Thus, the government can use price discrimination to buy-out about 2/3rd of the water freeing up an annual supply of 29 Mm^3 at a total permanent cost of JD 87.7 million and without substantially depressing the overall agricultural and rural economy of the area.

To finalize, it is important to discuss some of the differences and commonalities for the application and interpretation of nonparametric procedures for the estimation of *WTA* and *WTP* models. Even though in this paper we only present *WTA* models, the procedures outlined here can be used for nonparametric estimation of both the $E(WTP)$ and/or the entire demand curve using contingent valuation survey data. In addition, if the maximum *WTP* or *WTA* are assumed to be infinity, then one of the bounds of the estimates in each model will be unbounded: the upper bound of the *WTA* estimates and the lower bound of the *WTP* estimates. Hence, in the case of *WTP* models the nonparametric procedure will always allow to recover bounded conservative estimates of both the mean value and demand curves. However, bounded conservative estimates of the mean *WTA* value and the entire supply curve can only be obtained if an estimate of the maximum *WTA* value is available. In our specific application, the maximum *WTA* was obtained from the open-ended responses voluntarily provided by those farmers that answer "no" to the two bids offered.

WTA Regression Analysis

The *WTA* regression model results are shown in Table 4[2]. Model I is estimated on the basis of the responses to the discrete choice variable questions only (equation 23.5), whereas Model II also incorporates the information contained in the open-ended *WTA* value provided by farmers who answered NO to both bids (equation 23.6). Restricted versions of Models I and II including only an intercept were also estimated in order to obtain and compare the estimates of the unconditional mean and standard deviation of the distribution of *WTA* values (Cameron, 1988). Interestingly, the *WTA* mean and error variance estimates using Model II ($\hat{\mu} = 0.191, \hat{\sigma} = 0.219$) are higher than those obtained using Model I ($\hat{\mu} = 0.159, \hat{\sigma} = 0.072$). However, note that the mean *WTA* estimate from Model II is within only 1.4 of its standard error away from the mean estimate from Model I, i.e. the two estimates are statistically consistent with each other. The different error term variance estimates are explained by the fact that the dependent variable in Model II includes the open-ended responses, which means that the random components of the two models are not directly comparable (i.e., they are not nested).

[2] The models presented in Table 4 assume a normal distribution. There is little difference in the results when a lognormal distribution is assumed, which suggests that they are robust with respect to the distributional assumption.

Specifications of Models I and II including additional explanatory variables (Table 1) were initially estimated. However, since the corresponding parameter estimates were not significant from a statistical or an economic perspective, and given the small sample size and high levels of multicollinearity, some variables were excluded from the final models. Parameter values in the conditional mean of Model II are higher than those in Model I (in absolute terms). Moreover, Model II yielded a higher number of statistically significant parameter estimates. This result suggests that the use of the additional open ended question improves the efficiency of the parameter estimates.

The parameter estimates shown in table 4 measure the marginal effects of a one unit increase in the explanatory variable on the *WTA*. The signs of the parameter estimates corresponding to the variables in the final models are generally consistent across the two model specifications. In both models, water extraction costs and farmer's knowledge about the aquifer's ongoing depletion are found to have a negative effect on *WTA* whereas farmer's age and well ownership have a positive effect on *WTA* values. The sign of the price parameter is positive in Model II and negative but not significant in Model I.

Each additional year of age increases the farmer's predicted *WTA* value by JD 0.001/m^3 according to Model 1 and by JD 0.003/m^3 in Model 2. Thus, the models suggest that a 60 year old producer would have to be paid about JD 0.06/m^3 more than a 30 year old farmer (ceteris paribus), which is substantial in comparison to a mean *WTA* of between JD 0.159/m^3 (Model I) and JD 0.191/m^3 (Model II). This result might be due to the fact that older farmers, in general, could have a more difficult time finding an alternative income-generating occupation while younger producers can reap the benefits of both government payments for giving up their annual water supply and the income generated from another job. Also, psychologically, it might be more difficult for an older farmer to give up his water and agricultural lifestyle. The policy implication of this finding is that the government would likely have more success on getting younger producers to lease their water "rights" at possibly lower prices.

A JD 1.0/m^3 increase in water extraction costs is predicted to reduce an individual's *WTA* value by JD 0.029/m^3 in Model I and JD 0.044/m^3 in Model II. On the other hand, a JD 1.0/m^3 increase in the average price of agricultural products is predicted to increase and individual's WTA value by JD 0.141/ m^3 in Model II (the parameter is not significant in Model I). Although the direction of these effects is consistent with expectations based on the theoretical model, their magnitudes are relatively modest. In fact, these marginal effects translate into elasticity values of about 0.19 for the price variable and 0.08 for the cost variable. This might be partially explained by the fact that producers are being asked to forgive uncertain future revenues with a fixed but certain payment amount. Moreover, both the price and costs used in the estimation correspond to a specific year and it is unknown how these values compare to their long term averages.

The marginal effects of the dummy explanatory variables are interpreted relative to the dummy variables not included in the model (a farmer who does not know that the water table is dropping and that rents a well). Farmers who own a well are willing to accept JD0.026/m^3 and JD0.062/m^3 more than farmers that rent a well according to Models I and II, respectively. On the other hand, farmers who know that the water table is dropping are willing to accept JD0.021/m^3 and JD0.073/m^3 less than farmers that are not aware of the aquifer's depletion according to Models I and II, respectively. The effect of farmers' knowledge about the groundwater resource depletion on farmers' willingness to sell their water rights has immediate policy implications for water use in Jordan and also illustrates the effect of information on market outcomes. For example, informing farmers about the aquifer depletion will decrease their *WTA* and also decrease the costs of buying their water use rights.

Finally, regarding the variance specification of Model II, it is found that producers with higher application costs and farmers that know that the water table is dropping display more homogenous preferences.

Summary and Conclusions

This study has utilized data from a survey of farmers in the Mafraq-Azraq basin to examine the economic feasibility of water transfers from irrigation to urban water use. Farmers' responses to discrete contingent valuation questions were used to estimate the aggregate costs of buying their water use rights and also to identify factors affecting their willingness to accept values to sell their water use rights.

The theoretical models indicate that farmers' *WTA* for the water use rights is influenced by the same factors that influence farm profitability: output and input prices and other factors affecting both the production and the utility functions.

The econometric and modeling innovation is the utilization of contingent valuation and nonparametric procedures to estimate *WTA* models. We show that the estimation of the mean *WTA* and supply curves using nonparametric procedures require an estimate of the maximum *WTA* value. It is open to debate if researchers interested in using nonparametric procedures for *WTA* model estimation should always include an open ended follow-up question for individuals that answer no to both bids.[3] As mentioned previously, one of the reasons given for the adoption of referendum type CV elicitation formats (included discrete choice mechanisms) instead of open-ended formats was that the open-ended model invites strategic overstatement of both *WTP*

[3] In the case of the single bounded discrete choice elicitation method this would correspond to a second open-ended follow up question for those individuals that answer "no" to the first bid.

and *WTA* (Arrow et al., 1993). This means that the use of the extra open-ended question could result in an overstated maximum *WTA* value which is not necessarily a bad thing if what is required is a conservative estimate. This shortcoming of the nonparametric procedure should be weighed against the advantages of using a distribution free procedure. As shown in Haab and McConnell (1997) expected *WTP* (and hence expected *WTA* and the corresponding demand and supply curves) are highly dependent on the shape of the distribution assumed when parametric models are used.

Regarding our empirical application, supply curve estimates indicate the total amount of water that could be purchased from farmers at different water prices levels and can be used by the Jordan government to assess the potential costs and benefits of transferring water from the agricultural sector to others sectors of the economy. For example, it is estimated that water shadow price in Amman could reach values as high as JD47/m^3 by 2020 which is significantly above the JD1.81/ m^3 maximum *WTA* estimate from our models (Salman et al., 2006).

Water extraction costs and farmers' knowledge about the aquifer depletion were found to have a negative effect on *WTA* values whereas than the price of the agricultural products, farmers' age and well ownership have a positive effect on *WTA* values. The effect of farmers' knowledge about the groundwater resource depletion on farmers' willingness to sell their water rights has immediate policy implications for water use in Jordan and also illustrates the effect of information on market outcomes. Informing farmers about the aquifer depletion will decrease their *WTA* and also decrease the costs of buying their water use rights. Moreover, this result implies that informing farmers' knowledge about the resource depletion will shift the supply out, leading to lower water equilibrium prices.

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Table 1. Summary Statistics of Variables of the Sample of Jordanian Farmers

Variable	Mean	Standard error	Max	Min
Farming is Main Income Source (Yes=1, No=0)	0.625	0.487	1.000	0.000
Farmer Owns Well (Yes=1, No=0)	0.817	0.388	1.000	0.000
Farmer Lives on Farm (Yes=1, No=0)	0.365	0.484	1.000	0.000
Farmers' Age (years)	50.644	13.221	75.000	22.000
University or Technical Education (Yes=1, No=0)	0.308	0.464	1.000	0.000
Farmers Knows Water Table is Dropping (Yes=1, No=0)	0.769	0.423	1.000	0.000
Total Water Use (Mm^3)	0.142	0.072	0.454	0.010
Total Area Farmed (100 donums)[a]	2.535	1.837	8.200	0.300
Energy Costs of Pumping Water (JD/m^3)[b]	0.227	0.399	3.000	0.009
Government Payments for Water Extraction (JD/m^3)	0.002	0.006	0.038	0.000
Well Maintenance Costs (JD/m^3)	0.037	0.042	0.214	0.000
Costs of Well Rental (JD/m^3)[c]	0.178	0.037	0.929	0.000
Total Cost of Water Application (JD/m^3)	0.299	0.476	3.429	0.019
Average Price Received for Agricultural Products (1000 JD/T)	0.229	0.241	1.600	0.015
Number of farmers (n)		105		

[a] 1 donum = 0.10 Hectares
[b] 1 JD = 0.70 U.S. dollars
c Based on the sample of 19 farmers that rent wells.

Table 2. Responses to Double Bounded Dichotomous Questions (n=105)

First Discrete Choice Question	Yes		No	
Percentage of respondents (%)	20.00		80.00	
Average Price (JD/m^3)[a]	0.16		0.13	
Second Discrete Choice Question	Yes	No	Yes	No
Percentage of respondents (%)	12.40	7.60	47.60	32.40
Average Price (JD/m^3)	0.13	0.13	0.16	0.16

[a] 1 JD = 0.70 U.S. dollars

Table 3. Turnbull Willingness to Accept Distribution Function (n=85)[a]

Bid range (JD/m^3)[b]	Turnbull CDF
0-0.033	0.029 (0.021)[c]
0.033-0.067	0.029 (0.021)
0.067-0.100	0.275 (0.049)
0.100-0.133	0.334 (0.052)
0.133-0.167	0.511 (0.056)
0.167-0.200	0.589 (0.060)
0.200 -0.233	0.863 (0.046)
0.233 +	1.0
Lower bound population mean WTA (JD/m^3)	0.146 (0.007)
Upper bound population mean WTA (JD/m^3)	0.391 (0.114)
Log-likelihood function	-121.92

[a] Only 85 observations were used to estimate the distribution function since farmers renting the well were excluded from the sample

[b] 1 JD = 0.70 U.S. dollars

[c] Standard errors reported in parentheses are standard errors obtained using bootstrapping

Table 4. Estimation Results of the Willingness to Accept Model for Water Use Rights in Jordan

Variable	Model I		Model II[a]	
	Restricted	Unrestricted	Restricted	Unrestricted
Mean				
Intercept	0.159*** (0.008)	0.134*** (0.035)	0.191*** (0.023)	0.023 (0.06)
Average Price Received for Agricultural Products (1000 JD/T)		-0.009 (0.034)		0.141** (0.068)
Total Cost of Water Application (JD/ m^3)		-0.029* (0.189)		-0.044*** (0.008)
Farmer Knows Water Table is Dropping (Yes=1, No=0)		-0.021 (0.018)		-0.071* (0.056)
Farmer's Age (years)		0.001 (0.001)		0.003*** (0.045)
Well Ownership (Yes=1, No=0)		0.025 (0.021)		0.062* (0.045)
Standard deviation (σ)				
Intercept	0.072*** (0.007)	0.069*** (0.007)	0.229*** (0.022)	-2.062*** (0.355)
Total Cost of Water Application (JD/ m^3)				-3.044*** (0.795)
Farmer Knows Water Table is Dropping (Yes=1, No=0)				-0.733** (0.407)
Log-likelihood	-161.78	-158.23	-230.91	-219.49
Sample size	104		104	

[a] Heteroskedasticity in Unrestricted Model II was modeled using the multiplicative form $\sigma = \exp(\boldsymbol{\alpha}'\mathbf{z})$ where $\mathbf{z}$ is the vector of explanatory variables and $\boldsymbol{\alpha}$ is a parameter vector.

Note: Numbers in parenthesis are asymptotic standard errors. One asterisk (*) indicates significance at the 10% level, two asterisks (**) indicate significance at the 5% level, and three asterisks (***) indicate significance at the 1% level.

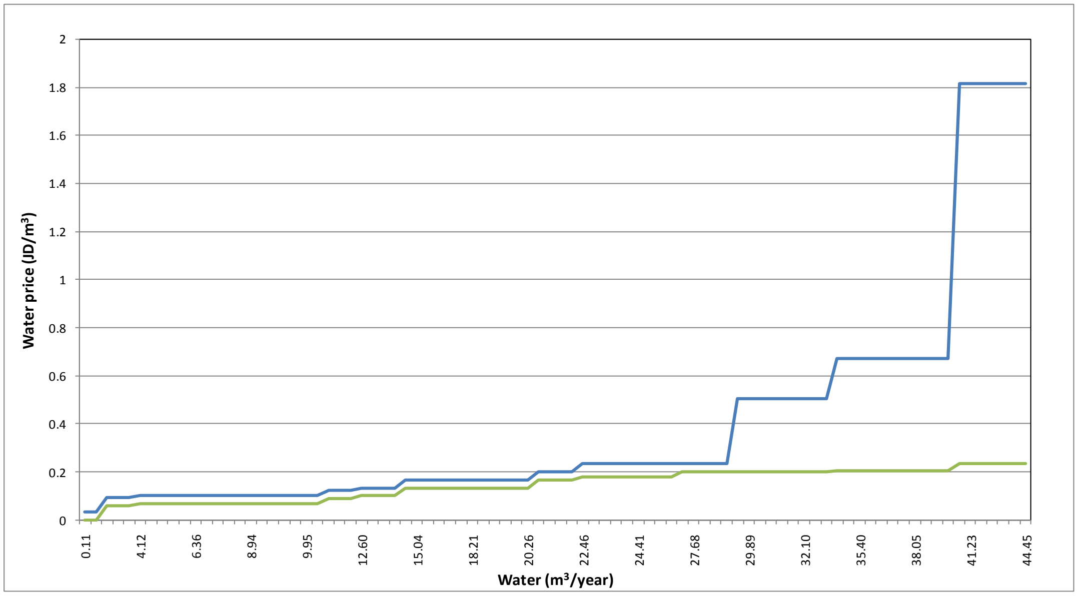

Figure 1. Estimated Water Supply Curve