Bayesian inference and prediction in Libya's emerging water-land-use complex

A. Ramali *
G. Holloway **

Abstract:

Water scarcity is a fundamental problem in Libya and most parts of the world especially in arid and semi-arid regions. The free of charge water supply and lack of management of the Libyan state encourages excessive use of water by farmers, leading to inefficient use of this important and vital resource. Therefore, this paper motivates the need for quantitative information to help policy-makers to undertake appropriate actions in order to overcome the water shortage problem in Libya. Consequently, the main aim of this study is to determine the economic value of water to sustain agricultural production by eliciting farmers' willingness to pay for water use under improved water supplies by using choice experiment modelling. To obtain this value estimates, Bayesian analysis of multinomial probit model based on using the Gibbs sampler was used to analyse the choice-experiment data of 400 interviewed farmers. Our obtained results showed that farmers are willing to pay for water depending on the perceived utilities from improved water supplies. On average, Libyan farmers are willing to pay 0.13, 0.11 and 0.12 LD/m^3 for quantity, quality and reliability of water, respectively, to use in their irrigated agriculture.

*Department of Agricultural Economics, Faculty of Agriculture, University of Tripoli, Tripoli, Libya
**School of Agriculture, Policy and Development, University of Reading, Reading, Berks RG6 6AR, UK

Key words: Bayesian analysis, choice experiment, multinomial probit model, willingness-to-pay, Libya.

Introduction:

Water scarcity, accessibility and environmental degradation are the major challenges facing the world, for urgent action calling to address serious issues related to the world's water-resources deficit. There are number of countries classified as water scarce, where their fresh water-resources annually do not exceed 1000 m^3/person/year, most of these countries are in the Middle East and North Africa (FAO, 2008). Many of these countries need to make fundamental changes in their policy of water management in order to increase the effective and efficient use of water-resources. Like most countries in the Middle East and North Africa, Libya is mostly arid and semi-arid zones covers a total of 1,759,540 square kilometres as stated by the General Authority for Information (GAI, 2008). According to Libyan General Authority for Agriculture (LGAA), groundwater is the main source of fresh water in the country, more than 80% of agricultural production produced from irrigated agriculture (LGAA, 2008). LGAA stated that the agricultural sector uses 78% of the total water resources in the country, which is an extremely high proportion. Presently, policy of the Libyan state is to supply water free of charge to farmers; however, this free supply has led to inefficient use of this important and vital resource. For these reasons, there is an urgent need to find a suitable and effective solution to rationalize and manage water use for agricultural purposes. This can be achieved by efficient pricing of water.

Libya is currently facing great challenges in meeting the growing demand for safe use of water, the country being one of the most arid regions on earth. The country is suffering from a shortage of water resources, despite the efforts including the construction of dams, desalination of seawater, treatment plants, sewage treatment station and the Man-made River Project. Water usage in the agricultural sector which represents the largest demand of available water resources in the country is especially challenging. According to the Libyan General Water Authority (LGWA) study conducted in 2005 to determine the water balance, groundwater supplies provide 95.6 % of the total supply. Surface water contributes 2.3 % of the amount used, whereas desalination of seawater and wastewater treatment are minor resources of only 1.4 % and 0.7 %, respectively. Water use in the country is as follows; agriculture has the highest consumption rate with 78 %, while the domestic sector consumes 12 %, and industry only 10 % of the total water used (LGWA, 2006). According to LGWA (2006), available data on water balances of Libyan basins (Figure 1) indicated that there is a major water supply deficit occurring in the Jaffara Plain basin and a less significant deficit in the Jabal Alakhdar basin due to population density and demand for arable land in the north-western and north-eastern regions of Libya. There is, however, no water deficit in the southern basins (Murzuk and Kufra-Sarir basins). The LGWA (2006) estimated that the total water supplies from all water resources in the country to be around 3820 Mm^3 per year. In short, Libyan water requirements are growing rapidly and the water deficit will be more than 4 billion m^3 in 2025 (Figure 2).

This research work was designed to find the suitable price of water in order to achieve social equality among farmers. Therefore, the main objective of this study was to determine the economic value of water to sustain agricultural production by eliciting farmers' willingness to pay (WTP) for water use under improved water supplies for agricultural purposes by using the choice experiment modelling.

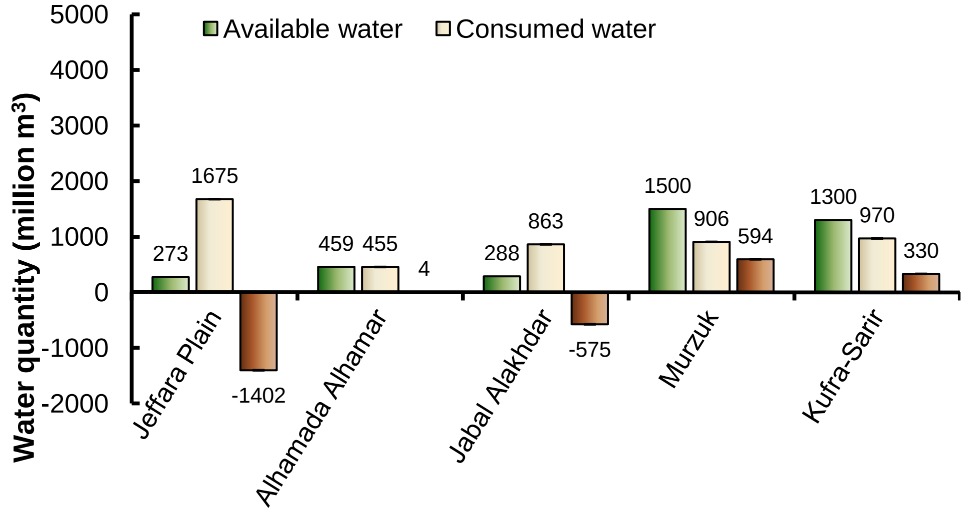

Fig. 1. Availability of groundwater, consumption and deficiency per basin.

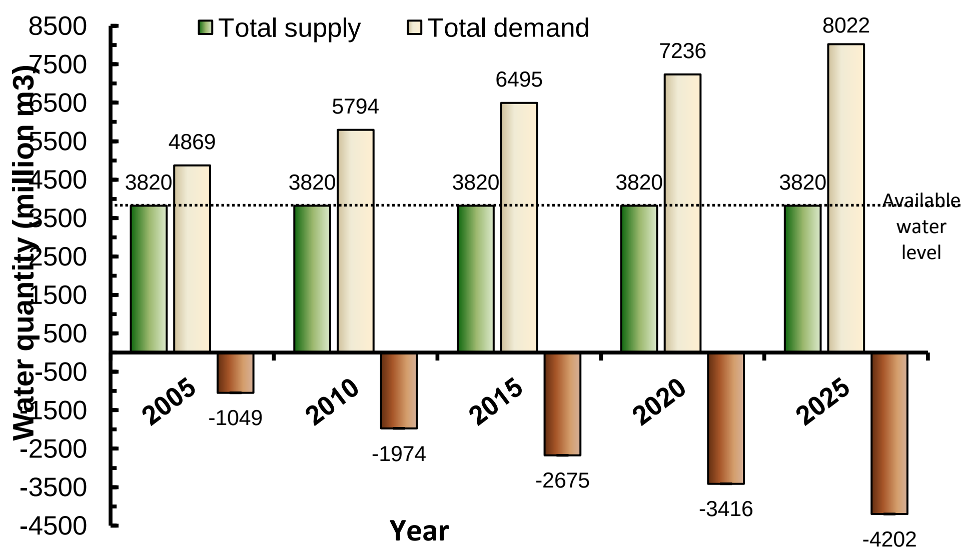

Fig. 2. Predicted water demand, supply and deficit through 2005-2025.

Materials and Methods:

Empirical model development for valuing water use:

Choice experiment design:

The essential step in choice experiment of estimating WTP is designing the questionnaire (Hensher *et al.*, 2005a). Establishing the choice experiment questionnaire depends primarily on consultations with groups of relevant individuals, known as focus group discussions (Blamey *et al.*, 2000). These consultations help to generate the type of information that should be included in the questionnaire such as determining the relevant attributes and their levels. To do this, three focus groups were carried out in order to help and design the choice experiment questionnaire. Two focus group discussions conducted for farmers, one in each study region, and a third is conducted for water supply representatives. Each focus group discussion had eight participants and was guided by the senior author of this paper. The number of participants was chosen to give all participants the opportunity to share their opinions and to provide diversity of perceptions and recommendations (Bateman et al., 2002). Farmers were invited to those focus groups meeting through local contact points and agricultural associations in each region. Selection of farmers was based upon certain criteria such as; their socioeconomic characteristics, water source, level of water shortage problem, farm size, and types of crops grown in the study regions. Water supply representatives were invited to attend the third focus group discussion and selected to represent different backgrounds and experiences. The purpose of the water supply representative's focus group was to obtain useful information about their attitudes and views toward water scarcity issues and adoption of water pricing policy as a solution to prevent the depletion of current water sources in the country. All attributes and their levels for choice experiment questionnaire are presented in table 1.

In general, the focus resides in establishing WTP for specific attributes, in contrast to forecasting and prediction, the "unlabelled experiment" is preferred (Hensher et al., 2005b). The unlabelled experiment is defined as the one which does not name the alternatives. The title Alternative 1 or Alternative A does not convey any information to the respondent other than 'this is the first alternative'. Using the full factorial design, the full number of possible choice sets is equal to LA for unlabelled choice experiment, where L is the number of levels and A the number of attributes (Hensher et al., , 2005b). As a result, applying the full factorial design for 4 attributes each one with four levels yields 2563 possible choice sets. Presenting 256 choice sets to respondents will place a significant level of cognitive burden on the respondents, in addition decreasing the rates of response and response reliability. However, one benefit of using full factorial design is that all of the main effects and their interaction can be estimated independent of one another (Hanley et al., 2001). In order to reduce the number of choice sets given to respondents, the fractional factorial design combined with the blocking strategy was used. The fractional factorial design is used to generate the smallest orthogonal design, where all attributes are statistically independent of one another in the orthogonal design, also it allows an investigation of main effects without being able to detect all interactions between attributes (Hanley et al., 1998). In order to generate statistically efficient design and make the choice experiment simple, Statistical Package for the Social Sciences SPSS software (version 15) was used to generate the design (SPSS, 2006). The SPSS software ensures that the design generated will be orthogonal, which consisted of only the main effects. The programme creates 32 choice sets, which are blocked into four partitions by using blocking strategy. The blocking attribute has four

[3] The number of choice sets that can be generated from 4 attributes, each with 4 levels, is 4^{*4} =256.

levels; therefore, the design has been broken down into four different partitions, each with eight choice sets. Consequently, four varied versions of the survey questionnaire are used each version comprising eight choice sets. An example of a choice card is provided in figure 3.

Table 1 Water attributes, description and attribute levels used inthe choice experiment design.

Attribute	Description*	Levels
Water quantity	Available quantities of water for agricultural purposes, which have effect on the cultivated area and the type of crops cultivated.	Partial sufficient: Means that the available amount of water can meet 25% of the needs of farm water. Average sufficient: Meets 50% of the needs of farm water. Sufficient: Meets 75% of the needs of farm water. More than sufficient: Meets all of the needs of farm water.
Water quality	The total amount and kinds of salts present in water which determine its suitability for water use for agriculture. This has the effect on the quality and quantity of agricultural production.	Poor water: Its use is restricted to well-drained permeable soil in production of salt tolerant crops. Good management practices must be used in order to maintain good physical condition of the soil. This water should not be used without advice from trained in irrigation water use. Fair water: It can be used successfully for most crops, if care taken to prevent accumulation of soluble salts including sodium in the soil. Good management and irrigation practices must be followed for this water. Good water: It is suitable for use in most crops under most conditions. Excellent water: The total soluble salt content and sodium percentage of this water are low enough that no problem should result from its use.
Water reliability	Government's sincerity to provide water to farmers.	Partially reliable: Water supplies can be relied upon to provide 25% of water demand. Average reliable: Water supplies can be relied upon to provide 50% of water demand. Reliable: Water supplies can be relied upon to provide 75% of water demand. Heavily reliable: Water supplies can be relied upon to provide 100% of water demand.
Price	The price would necessarily impact the water use in agriculture.	0.20 Libyan Dinar /m^3 0.25 Libyan Dinar /m^3 0.30 Libyan Dinar /m^3 0.35 Libyan Dinar /m^3

(*) Every attribute has four described levels in the experimental design.

Fig. 3. Illustrative choice set in the designed questionnaire.

Attribute	Option A (current situation of water supply)	Option B	Option C
Water quantity	Partially sufficient 25%	Partial sufficient 25%	Average sufficient 50%
Water quality	Salty poor	Fair water	Excellent water
Water reliability	Partial reliability 25%	Partial reliability 25%	Reliability 50%
Price	Free of charge	0.20 LD/m^3	0.30 LD/m^3

Please tick only one option.

Sites summary and respondent selection:

Generally, Libya comprises five agro ecological zones all with limited water resources. The Jaffara Plain and Jabal Alakhdar are the most affected by water-shortage problems, and are considered the most important agricultural regions in the country. Moreover, >75 % of the Libyan population is living in these two regions (GAI, 2008). For this reason emphasis is given to those regions as a first stage sampling selection for this study. The prevailing climatic conditions in the two regions are typically Mediterranean, where the rainfall is erratic in quantity, frequency and distribution (El-Darier and El-Mogaspi, 2009). The uses of available land depend primarily on the availability of water where most agricultural crops being irrigated. In view of these adverse factors, groundwater extraction rates increase to meet the growing water demand in both regions. Groundwater is considered the main resource of water and most of the agricultural activities depend upon groundwater supply for irrigation while the water supply from Man-Made River Project represents the second water resource in those regions (LGWA, 2006). The second stage involved selection of some districts from each region. The districts are selected to represent the main agricultural districts suffering from water shortage and increasing the demand to use water for their agricultural production. While, the third stage was selection of villages from districts that selected in each region. The selection of villages is based on current water resources as well as being the largest villages in terms of number of farms and farmers. The respondents are typical farmers selected within each village due to their responsibility of making farming decisions. The choice data are collected from 400 farmers of the Jaffara Plain and the Jabal Alakhdar regions using face-to-face interviews (two hundred being interviewed in each region). Compared with other methods, face-to-face interviews are commonly used in developing countries, because the mail, telephone and internet infrastructure are limited, poor and costly (Bateman et al., , 2002). Nevertheless, it must be acknowledged that there are risks associated with how farmers perceive attributes and their levels in choice-experiment design, and the cognitive burden of the exercise should not be overlooked when conducting interviews.

Choice experiment model:

Formally, the theoretical underpinning of choice models is based on Lancaster's 'characteristics' theory of goods (Lancaster, 1966), and on random utility theory that forms the basis of several theories and models of decision making and consumer judgment in the economics and psychology (Adamowicz et al., 1998; Manski, 1977; McFadden, 1974; Thurstone, 1927). Utility is derived from the characteristics of goods rather than directly from the goods themselves. These characteristics, or attributes, are the source of utility for an individual and they are produced either individually or through a combination of goods. Assume that utility depends on choices made from a set t. A choice set, t includes all possible alternatives in the choice experiment, made up of a finite number of mutually exclusive alternatives, where the choice set is exclusive, and the ordering of alternatives has no effect on the choice process undertaken by the respondent. Then the representative individual is assumed to have a utility function of the form:

$$U_{ij} = U(X_{ij}, S_i) \quad \text{for} \begin{cases} i = 1,2, \dots, n \\ j = 1, \dots, m \end{cases} \forall j \in t \quad (1)$$

Where, for any individual, i, a given level of utility will be associated with alternative water supply, j. Alternative j will be chosen over some other alternative g if $U_{ij} > U_{ig}$. The utility derived from any alternative is assumed to depend on the attributes, X, of that alternative. These attributes may be viewed differently by different individuals, whose socioeconomic characteristics, S, will also affect utility. According to, the random utility framework (Hanley et al., , 2001), the indirect utility function for each respondent can be partitioned into parts; a deterministic and, in principle, observable part, and a random unobservable part. Then equation (1) can be rewritten as:

$$U_{ij} = V_{ij} + e_{ij} \quad \text{where} \qquad V_{ij} = X'_{ij}\beta + Z_i\delta \qquad (2)$$

Where, β and δ denote corresponding parameters and the probability that individual, i, will choose alternative, j over another alternative, g, is given by:

$$Pr_{ij} = Pr\big(U_{ij} > U_{ig}\big), \forall\, j \neq g \quad \forall g \in t$$

$$= Pr\big(V_{ij} + e_{ij} > V_{ig} + e_{ig}\ \forall\, j \neq g\big) \quad \forall g \in t$$

$$= Pr\ (e_{ig} - e_{ij} < V_{ij} - V_{ig}\ \forall\, j \neq g\ \forall g \in t \qquad (3)$$

$$Pr_{ij} = \int_{ei} I(e_{ig} - e_{ij} < V_{ij} - V_{ig}\ \forall\, j \neq g) f(e_i) de_i \qquad (4)$$

where $I(.)$ is an indicator function, equalling 1 when the expression in parentheses is true and 0 otherwise (Train, 2003). The probability expression in (3) is the cumulative distribution of the probability that the difference in error, $(e_{ig} - e_{ij})$ is below the difference in observed quantity $(V_{ij} - V_{ig})$. This gives rise to (4), which is a multidimensional integral that takes closed forms only for certain choices of distribution, e_i, where the choice of $f(e_i)$ has a crucial impact on the behaviour of the choice-model.

Multinomial probit model development:

The multinomial probit model can be an alternative to the multinomial logit model for situations in which one of a finite number of outcomes are observed conditional on a set of covariates (Train, 2003). The computational complexity of fitting the multinomial probit model and its requirement for high-dimensional integrations, limits the application of this very useful and appealing model (Imai and van Dyk, 2005). However, recent developments in simulation methods, such as simulated maximum likelihood or method of simulated moments, and Bayesian analysis have raised renewed interest in the multinomial probit model as a model of choice even when the choice set becomes larger (Breslaw, 2002; Chintagunta, 1992; Geweke et al., 1994). Also, the multinomial probit model is often used to analyze the discrete choices made by individuals recorded in survey data (Imai and van Dyk, 2005). Bayesian analysis allows us to make exact finite sample inferences for choice model estimates and variables, instead of relying on large sample theory which would require a large sample size for accurate asymptotic approximations (McCulloch and Rossi, 1994). In this research, Bayesian analysis of multinomial probit model, based on using the Gibbs sampler, is used to analyse the choice-experiment data. Bayesian analysis of the multinomial probit model is given in McCulloch and Rossi (1994) and reconsidered by Nobile (1998). The utility derived from a water supply, j, in the choice set, t, by individual, i, is given by (2) as:

$$U_{ijt} = X'_{ijt}\beta + S_i\delta + e_{ijt} \quad where \ j = \text{alternatives } A, B, \text{and } C \qquad for \begin{cases} i = 1,2,\dots,n \\ j = 0,1,\dots,m \\ t = 1,2,\dots,T \end{cases}$$

Where, $\mathrm{U_{ijt}}$ indicates that alternative "j" was chosen from choice set "t", by the farmer "i", where there are three alternatives of water supplies in each choice set "t", namely: alternatives A, B, and C. Here, alternative A, indicates the status quo of water supply, while alternatives B and C indicate hypothetical, alternative water supplies. In the multinomial probit model, we assume that error terms ($\mathrm{e_{ijt}}$) follow a multivariate normal distribution with a mean-vector of zero and variance-covariance matrix $\sum$, allowing disturbances to be correlated across water supply. Within this paper, three multinomial probit models were estimated. In the first model, the basic model only attributes are employment as the explanatory variables, which comprise water quantity, water quality, water reliability and price. While, in the second and third models, both attributes and socio-economic variables are used. For the purposes of estimation, we assume diffuse proper priors for the parameters in the model. Bayesian estimation of the multinomial probit model is achieved through Markov Chain Monte Carlo simulations using the Gibbs sampler algorithm by McCulloch and Rossi (Imai and van Dyk, 2005; McCulloch et al., 2000; McCulloch and Rossi, 1994). This procedure allows us to use finite-sample inferences instead of large sample theory for which a large-sample size is required for accurate asymptotic approximations for discrete dependent variables (Alvarez and Katz, 2009; McCulloch and Rossi, 1994).

The Markov Chain Monte Carlo, multinomial probit algorithm:

In this paper, the Markov Chain Monte Carlo approach to the problem of posterior inference for the multinomial probit model is to construct a method which provides the equivalence of an indirect simulator from the posterior distribution because of direct simulation from the posterior distribution is not possible (McCulloch and Rossi, 1994). The indirect method is the Gibbs sampler which relies only on drawing from separate conditional distributions. The Gibbs sampler introduced by Geman and Geman (1984) and Tanner and Wong (1987) relies on the remarkable results that iterative, recursive sampling from the full set of conditional distributions results in a sequence of random variable which converge in distribution to the target distribution of interest. The Gibbs sampler is discussed in Gelfand and Smith (1990), Casella and George (1992), Smith and Roberts (1993) and Tierney (1994). McCulloch and Rossi (1994) are first used the Gibbs sampler in order to draw inferences from the multinomial probit model. In the Gibbs-sampler approach, we can break the full set of parameters into four groups and draw these groups successively to form the Gibbs sampler. This strategy depends on the fact that, the Bayesian analysis of the multinomial probit model reduces to analysis of the standard linear model results (McCulloch and Rossi, 1996), given the data, the Gibbs sampler proceeds by drawing from the set of fully conditional distributions. The Gibbs sampler is a Monte Carlo method for estimating the desired posterior distribution. Its greatest advantage is the ease of implementation, which is attained at the cost of computational efficiency (Zeger and Rizaul Karim, 1991).

Estimation:

MATLAB release 2010 (MathWorks, Massachusetts, USA) was used to estimate the multinomial probit model, by using Relatively Diffuse Priors. As mentioned in the estimation that we have used the Gibbs sampler algorithm. From our initial information on likely parameters values, we have incorporated suitable proper prior distributions in the model. For each model, the log marginal likelihood is estimated as described in the next section. The log marginal likelihood is commonly used in the Bayesian literature, which is preferable for models comparison and testing (Balcombe et al., 2009). It gives the characteristic for a model fit (Bos, 2002), and the best performing model is the one of largest log marginal likelihood which will be selected and used in the subsequent estimations of the WTP.

Extracting willingness to pay (WTP) quantities:

The utility function of the model, with the exception of the error term, is an observable term (V_{ij}) in equation (1). This component can be expressed as a linear function of an attribute vector namely.

$$\mathrm{V} = ASC + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \qquad (5)$$

The WTP is calculated by computing the rate of substitution between the attribute of interest and the cost attribute (Bateman et al., 2003), in other words, taking the total derivative of the utility index. As mentioned in equation (5), the estimated coefficients of the attributes are assumed to be linear parameters and hence can be used to estimate the tradeoffs between the attribute that respondents would be willing to make. Therefore, when the parameter estimates are obtained by using empirical models, WTP can be estimated using the formula.

$$WTP = -\frac{\beta_a}{\beta_{price}} \quad (6)$$

Where β_a is the coefficient of attribute a, and β_{price} is the coefficient of the price attribute. This monetary value is called the “part-worth” or the “implicit price” of the attribute (Bennett and Blamey, 2001). The implicit prices reflect the marginal WTP for a marginal change in each attribute. The consumers’ WTP is becoming increasingly popular and is one of the standard approaches that is used by market researchers and economists to place a value on goods or services for which no market-based pricing mechanism exists (Gil et al., 2000; Koss and Khawaja, 2001). The WTP estimates are obtained from the preferred model. In order to estimate the WTP values as suggested by Bateman et al. (2002), the status quo option is included in the utility function to achieve a welfare measure consistent with demand theory.

Results:

The preferred multinomial probit estimates:

The value of the log marginal likelihood of the multinomial probit model with attributes and some socioeconomic variables is larger than the multinomial probit model with attributes only and multinomial probit model with attributes and all explanatory variables. This suggests the multinomial probit model with attributes and some socioeconomic variables provides a better description of the data than the other two multinomial probit models. This explains why; this model is called the preferred model for this study. Table 2 presents the posterior mean and 95% Bayesian confidence intervals for the parameters of the preferred multinomial probit model. In order to capture unobservable influences beyond attributes present in the choice sets, the alternative-specific constant is incorporated in the econometric analysis of the multinomial probit model. The alternative-specific constant denotes the preferences for other water supplies alternatives compared to the current water supply. The coefficient of the alternative-specific constant is negative and significant, implying that there is some degree of status quo bias. This means that, all else held constant, farmers would prefer to move away from the status quo situation (Hanley et al., 2005) and towards improved water supplies even if they would have to pay for these. This confirms that 86.75 % (347 out of 400 farmers) of the respondents have willing to pay for water use in agriculture. The summaries of posterior densities explicitly reveal the relative influence of water attributes and socioeconomics variables on the choice of water supplies. Judging from the statistical results, the coefficients of all the water attributes are significant, and the signs of the coefficients are consistent with our expectations. For instance, the coefficients of water quantity, water quality, and reliability are positive. This means that as the level of any of these attributes increases, the utilities of farmers are increased and the probability of choosing alternatives rather than the status quo alternative increases. On the contrary, the coefficient of the "price" attribute is negative and statistically significant, which is consistent with standard economic theory. The negative sign of the price coefficient implies that farmers prefer water supplies involve lower prices. This confirms that increasing levels of price have a negative effect on utility. Heterogeneity is often the result of differences in the social, economic, demographic and attitudinal characteristics of the respondents (Boxall and Adamowicz, 2002). Therefore, inclusion of socioeconomic characteristics in the analysis is important in order to identify their influence on the choice for paid alternatives of water supplies, and hence on the WTP for water. The results show that, the posterior means of age, water scarcity, education level, farm income, irrigated area and farm ownership have positive signs, and hence their influences on the choice for paid alternatives of water supplies are positive. On the other hand, the posterior means of the remaining variables, namely water consumption and cost-of-water pumping, have negative effects on the choice for paid alternatives of water supplies, and hence on the WTP for water. In summary, our results are quite consistent with a priori beliefs and economic theory.

Table 2 Variable estimation results of the multinomial probit model.

Variables	**Preferred Model**	
	Mean	**[95% Bayesian confidence intervals]**
ASC	-0.261 *	[-0.2736,-0.2561]
Water quantity	0.130 *	[0.1215, 0.1357]
Water quality	0.110 *	[0.1044, 0.1239]
Water reliability	0.123 *	[0.1146, 0.1315]
Price	-0.986 *	[-1.0168,-0.9790]
Socioeconomic variables		
age	0.134*	[0.1235, 0.1464]
Education level	0.695*	[0.6887, 0.7076]
Farm income	0.491*	[0.4843, 0.5018]
Irrigated area	0.413*	[0.4041, 0.4222]
Farm ownership	0.126*	[0.1135, 0.1397]
Water scarcity	0.230*	[0.2252, 0.2376]
Water consumption	-0.328*	[-0.3374,-0.3191]
Cost of water pumping	-0.477*	[-0.4833,-0.4715]
Number of participants	400	
Number of observations	3200	
Log marginal likelihood	736.36	

∗ Significant at 95% level of Bayesian confidence intervals.

Willingness to pay (WTP) estimates:

The preferred estimate of WTP for water use for agricultural purposes is an essential aim and the estimates of the preferred multinomial probit model (Table 2) are used to obtain farmers' marginal WTP. After developing Gibbs sampling methodology for each multinomial-probit formulation, the resultant marginal WTP estimates are derived from the preferred model. The WTP estimates explain choices between the alternatives solely as function of their attributes. Calculate the marginal rates of substitution between the attributes using the coefficient for price as numeraire. This implies that it can interpret the ratios as average marginal WTP for a change in each attributes, as argued by Hanemann (1984). Thus, the willingness to pay estimates shows that the WTP for a change in price by one unit keeping all other water attributes constant. Farmers are willing to pay for water supplies depending on the perceived utilities from those water supplies. The farmers are preparing to pay for an average 0.13, 0.11 and 0.12 LD/m3 for quantity, quality and reliability of water, respectively, when each water attribute be at the best level (Table 1). The results reveal that the total amount that a farmer is willing to pay for water use in agriculture to approximately 0.36 LD/m3. This finding is too close to the findings obtained from focus groups discussions, where participants agreed on a maximum of about 0.35 LD/m3 of water use for agricultural purposes. In addition, according to the annual farm income in the sample, the total WTP estimates represents about 12 % of the annual gross farm income, which is significant and under scores, further, the importance, and the significance in perceptions across farms, that water is a highly valuable, constraining resource in Libyan agricultural production. Where the most important agricultural crops cultivated by the farmers in the sample are, vegetables and fruit trees especially onions, tomatoes, potatoes, eggplant, sweet pepper, cucumber, pumpkin, leaf vegetables, watermelon, grapes, olives, and citrus. Overall, the WTP estimates of this study provide preliminary information to help policy-makers take appropriate actions with regard to put scenarios of water pricing policy in Libya.

Discussion and Conclusion:

In general, this study motivates the need for extra quantitative information that sheds light on the important problem of valuing water use and water resources within Libyan agricultural sector. The current policy of the Libyan state is to supply water free of charge to farmers. This free availability encourages excessive use of water by farmers, leading to inefficient use of this vital resource. Nationally, this research study provides useful results where the values of WTP can be used to assist decision-makers in the policy implementation to undertake appropriate actions regarding water pricing for agricultural purposes in order to overcome the current water scarcity problem. Also, our data presents preliminary estimates on the valuations of the attributes of water supply and has identified some ancillary socio-demographic factors that influence the valuation rates. Hence, the key merit of this research paper lies in addressing the gap in the literature on the estimation of WTP for using water, as an economic good, in agriculture by applying Bayesian analysis of multinomial probit model to analyse the choice-experiment data.

استدلال بايزي والتنبؤ به في استخدام المياه والأرض المعقد في ليبيا

امــان الرمالي *
غارث هولووي **

المستخلص:

ندرة المياه مشكلة رئيسية في ليبيا وأغلب أجزاء العالم خاصة في المناطق الجافة وشبه الجافة. الحصول على المياه بدون ثمن وغياب الإدارة في الدولة الليبية شجع على الاستخدام المفرط للمياه من قبل المزارعين نتج عنه استخدام سيء لهذه الثروة الحيوية الهامة. هذه الورقة تحفز الاحتياج للمعلومات الرقمية لتساعد صانعي القرار لاتخاذ التدابير المناسبة للتغلب على مشكلة نقص المياه في ليبيا. تهدف هذه الدراسة الي تقدير القيمة الاقتصادية للمياه لإنتاج زراعي مستدام ولاختبار مدى رغبة المزارعين لدفع تكلفة المياه المستخدمة تحت ظروف تحسين توفير المياه باستخدام نموذج تجربة الاختيار (Choice Experiment Modelling). للحصول على هذه القيمة التقديرية، تم استخدام تحليل بايزي لنموذج بروبيت متعدد الحدود (Multinomial Probit Model) المترتب عن عينات جيبس (Gibbs) لتحليل بيانات تجربة الاختيار لعدد 400 مزارع تمت مقابلتهم, حيث أظهرت النتائج رغبة المزارعين للدفع اعتمادا على تحسين ظروف توفير المياه. في المتوسط المزارع يرغب في دفع LD/m^3 0.13, 0.11, 0.12 وذلك للكمية والنوعية والمصداقية على التوالي للاستخدام الزراعي.

الكلمات الدالة: تحليل بايزي، تجربة الاختيار، نموذج بروبيت متعدد الحدود, الاستعداد للدفع، ليبيا.

* قسم الاقتصاد الزراعي، كلية الزراعة، جامعة طرابلس، طرابلس– ليبيا

** قسم الاقتصاد الزراعي، كلية الزراعة والسياسة والتنمية، جامعة ريدنج، المملكة المتحدة

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