Economic Valuation of Improved Irrigation Water Use: The Case of Woliso District, South West Shoa Zone, Oromia National Regional State, Ethiopia

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Abstract
As scarcity of irrigation water is rising, pricing of agricultural water and cost recovery can play a significant role in promoting water use efficiency. Hence, the main objective of this study was to analyze economic valuation of improved irrigation water use. Both primary and secondary data were used to achieve the objective. Cross sectional data were collected from 251 households using a two-stage sampling technique (purposive and random sampling techniques) from four kebeles of Woliso District through a semi-structured questionnaire. The result of the study showed that 92.43% of the households were willing to pay for improved irrigation water use and only 7.57% were not willing to pay. The mean willingness to pay for the use of improved irrigation water from the double bounded dichotomous question of Seemingly Unrelated Bivariate Probit model was Birr 575.23 per year per *timad* (0.25 ha). On the other hand, the mean willingness to pay from open-ended questions was Birr 562.25 per year per *timad* (0.25 ha). Thus, appropriate irrigation water pricing will make the user more aware of the resource scarcity, creating more value for the improved irrigation, leading to efficient management of the improved system.

Keywords: Economic Valuation; Irrigation; Seemingly Unrelated Bivariate Probit; Woliso.

1. Introduction

Water is used as an input in most production hence important for economic development. Globally, among all economic sectors, agriculture is the biggest consumer of fresh water, and a sector characterized with intense water use with low efficiency. As a result, water scarcity is on the rise with increased demand of households for water in agriculture. Under-pricing of water and lack of cost recovery leads to undesirable outcomes such as excessive use, pollution, resource misallocation and non-sustainable water supply service. When water charges are low, people tend to use water carelessly. Therefore, better water allocation could be achieved if the economic value of water is known by use, region and season (Omondi, 2014).

Irrigation is believed as a key for food security and poverty reduction in Ethiopia. As a result, developments in the Ethiopian irrigation system have shown great advancements so as to assure Ethiopian livelihoods especially in the rural areas. Consequently, the government and peoples of Ethiopia believes that irrigation can play a significant role for food security enhancement and economic growth. This indicates more investments on the area have paramount importance for the development of the country. However, the contribution of irrigation to the national economy as compared to its potentials is non-negligible (Gebremeskel and Kebede, 2015). The finding of Eneyew (2014) similarly revealed that although Ethiopia is considered as a water tower of Africa, only 5% irrigation potential is developed up to recent. Therefore, as agriculture will remain the main driver of the rapid and inclusive economic growth and development of the country, GTP II now aims to enhance the uses of the country's water resources. In this line, primarily focus is at attaining food security, generating foreign exchange and supplying raw-materials to industries with developing and expanding of efficient, sustainable and indigenous-technology based medium and large scale irrigation farming. As a result, irrigation based agriculture development is promoted (NPC, 2016).

Looking at the area of interest, namely Woliso District, there is a water source from Walga River which is suitable to develop and maintain irrigation project scheme, and resolve the dependency on rainfed agriculture. However, there is no a well-constructed irrigation scheme and regulation to use the resource. Yet the irrigation provisions around the River have no water storage capacity since water comes out to the command area from the rivers through traditional means. This will create a problem at the time of dry season at which more water for irrigation is needed by huge number of users. Moreover, there is no lined canal, and the water wastage is a serious problem of the area. Hence, in order to improve the existing irrigation water supply, the water storage capacity should be enhanced. To do so, dam construction is a prerequisite to reserve water which enables farmers to get sufficient water flow throughout the year (WWIDAO, 2016). Currently, the government of the country is focused on the planning and measures of different activities in order to improve the irrigation system via concentrating on the supply side and seems to neglect the effective demand of the majority of irrigation water users. However, Hudu *et al*. (2014) revealed that the implementation of these measures requires that farmers are willing to assist in recovering the cost of the management, maintenance and operation of the irrigation system that will result from the improvement. Therefore, the need of examining economic valuation of improved irrigation water use is timely research, assuming the irrigation system is improved.

Previously, a number of studies were conducted using CVM in the valuation of irrigation water improvement by the conventional method (Mezgebo *et al*., 2013; Alemayehu, 2014; Birhane and Geta, 2016), but a few in estimation of improved irrigation water use by using the parametric bootstrapping approach as a whole and particularly in Ethiopia. Therefore, the objective of this study is to elicit economic valuation of improved irrigation water use in Woliso District of Ethiopia by employing parametric bootstrapping approach method.

2. Research methodology

2.1. Description of the Study Area

The study was undertaken in Woliso District of South West Shoa Zone of Oromia National Regional State. Woliso District is located at a latitude and longitude of 8° 32′ 23.0″ N and 37° 58′ 16.3″ E in the Southern West part of the country along Finfinne to Jimma main road, extending from 90-140 km from the capital city of the country, Finfinne. Topographically, it is characterized by plateaus, mountains, hills and plains. Altitude wise, the district lies between 1600 and 2880 meter above sea level. Simela, Karfefe and Rogda are the major mountains found in the district. Several perennial rivers (Walga, Rebu, Kono, Menisa, Dedebo, etc.), intermittent streams (Gute, Osole, Boye, Dergu, Atabela. etc.) and springs (Kora, Lencho, Boye, etc.) are found in the district. Agro-ecologically, it is classified into *weinadega* (70%) and *dega* (30%) zones. Chromic and Vertisol are the dominant soil types found in the district. The largest river in the district, Walga River that located at 8 km from Woliso town is a major source of irrigation water of the farmer (WWAdO, 2016).

The population of the district is projected at about 171,150 persons in 2014, of which 85,175 are male and 85,975 females. From the total population 3,622 are urban dwellers whereas 167,528 are rural people. It is the most densely populated district of the zone (Beyera, 2004).

The district has a long history of traditional irrigation practices and indigenous knowledge. Hence, it is possible to grab the opportunities and capitalize on. Accordingly, the households of the district are used to produce mostly different crops. However, there is a low institutional support for both irrigation users and non-users (CSA, 2013).

2.2. Data type, Sources and Methods of Data Collection

For this study, both primary and secondary data were used. The primary data were collected from sample households in the study area through semi-structured questionnaire using face to face interview. Besides, the data were generated by interview of the District Irrigation Development Authority Offices workers and supplemented by Focus Group Discussion (FGD) to generate qualitative information on the pre-test. Secondary data were also collected from the District Irrigation Development Authority Office and other relevant sources.

A pre-test of the draft questionnaire was done on 25 households in order to determine sets of bids, and to select appropriate wording and ordering of questions. However, the responses of these households were not included in the analysis in order to avoid the bias. After making the necessary adjustments to the draft questionnaire and setting bid prices, the final questionnaire was developed. Accordingly, the most frequently stated values were then selected as a starting value (price) for the double bounded dichotomous choice format. Household heads were then presented with the willingness to pay question that has any of the five different starting bid amounts determined: 200, 300, 400, 600, and 700 Birr. As Cameron and Quiggin (1994) stated, sets of bids were determined for double bounded dichotomous choice format by making twice the initial bid if the first response is "Yes" and half of it if the response is "No". Accordingly, the sets of bids in this study are (200, 100, 400), (300, 150, and 600), (400, 200, 800), (600, 300, 1200), and (700, 350, 1400).

2.3. Sampling Technique and Sample Size

The study used a two-stage sampling technique (both a purposive and random sampling techniques) in the selection of the study site and the sample households, respectively. In the first stage, four *kebeles* (namely Badessa-Koricha, Gute-Godeti, Ciracha-Wanberi, and Gurura-Baka) were purposively selected from 37 rural *kebeles* of Woliso District based on representativeness to the major irrigation users of the Woliso District, proximity to the source of water i.e. their irrigable farm land is close to the river that used as the major irrigation source, and personal experience in irrigated farm in the area. In second stage, irrigation water user farm households were selected randomly from each sample *kebele* using probability proportional to sample size.

In this study, a simplified formula provided by Yamane (1967) is used to determine the required sample size at 95% confidence level and 6% level of precision.

$$n = \frac{N}{1+N\,(e)^2} \tag{1}$$

Where n is the sample size, N is the population size (total irrigation water user households), and e is the level of precision. The district has a total of 2,701 irrigation water user households (WWIDAO, 2016). Hence, the desired sample size is 251.

2.4. Methods of Data Analysis

Econometric Model Specification

Using CVM, the value of irrigation water to a user is taken as the maximum amount that the user will be willing to pay for the use of this resource. Accordingly, a household head was asked how much he/she is willing to pay (WTP) for the improved irrigation water use. Therefore, in order to quantify the households willingness to pay the Seemingly Unrelated Bivariate Probit model was employed for this study. It is an alternative approach to control for unobservable heterogeneity, as it provides a way of dealing with two separate binary dependent variables (Greene, 2008).

Following Haab and Mc Connell (2002), the econometric modeling for the formulation of double-bounded data is given as:

$$WTP_{ij} = \mu_i + \varepsilon_{ij} \tag{2}$$

Where:

WTP_{ij} = Is the j^{th} respondent's WTP and i=1, 2 represents first and second answers;

μ_1, μ_2 = Is the mean value for first and second response, and

ε_{ij} = Unobservable random component.

To construct the likelihood function, the probability of observing each of the possible two-bid response sequences (yes-yes, yes-no, no-yes, no-no) are given as follows. The probability that the respondent i answers to the first bid and to the second bid is given by:

$$\Pr(\text{yes, no}) = (WTP_{1i} \geq t^1,\ WTP_{2i} < t^2) \tag{3}$$
$$= \Pr(\mu_1 + \varepsilon_{1i} \geq t^1,\ \mu_2 + \varepsilon_{2i} < t^2)$$
$$\Pr(\text{yes, yes}) = (WTP_{1i} > t^1,\ WTP_{2i} \geq t^2)$$
$$= \Pr(\mu_1 + \varepsilon_{1i} > t^1,\ \mu_2 + \varepsilon_{2i} \geq t^2)$$
$$\Pr(\text{no, no}) = (WTP_{1i} < t^1,\ WTP_{2i} < t^2)$$
$$= \Pr(\mu_1 + \varepsilon_{1i} < t^1,\ \mu_2 + \varepsilon_{2i} < t^2)$$
$$\Pr(\text{no, yes}) = (WTP_{1i} < t^1,\ WTP_{2i} \geq t^2)$$
$$= \Pr(\mu_1 + \varepsilon_{1i} < t^1, \mu_2 + \varepsilon_{2i} \geq t^2)$$

The i^{th} contribution to likelihood function becomes;

$$L_i\left(\frac{\mu}{t}\right) = \Pr(\mu_1 + \varepsilon_{1i} \geq t^1,\ \mu_2 + \varepsilon_{2i} < t^2)^{YN} * \Pr(\mu_1 + \varepsilon_{1i} > t^1,\ \mu_2 + \varepsilon_{2i} \geq t^2)^{YY} * \Pr(\mu_1 + \varepsilon_{1i} < t^1,\ \mu_2 + \varepsilon_{2i} < t^2)^{NN}$$
$$* \Pr(\mu_1 + \varepsilon_{1i} < t^1, \mu_2 + \varepsilon_{2i} \geq t^2)^{NY} \tag{4}$$

Where:

t^1 = First bid price, t^2=Second bid price

YN= 1 for yes-no answer, 0 otherwise;

YY= 1 for yes-yes answer, 0 otherwise;

NN= 1 for no-no answer, 0 otherwise;

NY= 1 for no-yes answer, 0 otherwise.

This formulation is referred to as the Bivariate Discrete Choice Model. Assuming normally distributed error terms with mean 0 and respective variances σ_1^2 and σ_2^2, then WTP_{1j} and WTP_{2j} have a bivariate normal distribution with means μ_1 and μ_2, variances σ_1^2 and σ_2^2 and correlation coefficient ρ. Given the dichotomous responses to each question, the normally distributed model is represented as bivariate probit model.

The i^{th} contribution to the bivariate probit likelihood function is given as:

$$L\left(\frac{\mu}{t}\right) = \Phi_{\varepsilon1\varepsilon2}\left(d_{1i}\,{}^{(t^1-\mu)}/_{\sigma_1}\right), \left(d_{2i}\,{}^{(t^2-\mu)}/_{\sigma_2}\right),\ d_{1i}d_{2i} \tag{5}$$

Where:

$\Phi_{\varepsilon1\varepsilon2}$ = The bivariate normal cumulative distribution function with zero means, $d_{1i} = 2y_{1i} - 1$ and $d_{2i} =$

$2y_{2i} - 1$
y_{1i} =1 if the response to the first question is yes, and 0 otherwise
y_{2i} =1 if the response to the second question is yes, and 0 otherwise
ρ = Correlation coefficient
σ = standard deviation of the error.

After running regression of dependent variable (yes/no indicator), on a constant and on independent variables consisting of the bid levels, the mean WTP value is determined following Jeanty (2007). Accordingly, the mean WTP and 95% confidence intervals are calculated using the approach developed by Krinsky and Robb (1986), sometimes known as the parametric bootstrapping approach. Therefore, the mean WTP value of improved irrigation water can be calculated as follows:

$$\text{Mean WTP} = \frac{\bar{X}\beta'}{\beta_o} \quad (6)$$

Where $\bar{X}$= Row vector of sample mean including 1 for the constant term,

$\beta'_{(k-1\times1)}$ = Column vector of estimated coefficients,

β_o = Coefficient on the bid variable, and in constant-only models, $\bar{X}$=1 and β' is the coefficient on the constant term.

Following to Haab and Mc Connell (2002), the mean WTP from the open ended contingent valuation responses can be estimated as:

$$\text{Mean WTP} = \sum_{i=0}^{n} \frac{y_i}{n} \quad (7)$$

Where n is the sample size and y_i is maximum amount of willingness to pay reported by households.

3. Results and discussions

3.1. Households' Willingness to Pay for the Improved Irrigation Water

In the final survey, five (200, 100, 400), (300, 150, 600), (400, 200, 800), (600, 300, 1200), (700, 350, 1400) set bid prices for the corresponding valuation question were given. These were set following what we have obtained from the pilot survey. Starting from heads of households who were asked for willingness to pay for the improved irrigation system, the data revealed that 92.43% were willing to pay for improved irrigation water use and only the rest 7.57% were no willing to pay for the improved irrigation water use. The stated price is value that the users are willing to pay for the use of improved irrigation water use in this case.

To identify whether these responses are protest zero responses or not, a follow-up question was raised to the interviews. The reason for zero willingness to pay was purely an economic reason. For instance, one interviewee said the following: 'I cannot afford the payment, as I do not have sufficient amount of money'. Hence, none of them were considered as protest answers.

As indicated in Table 1, one can understand from the joint frequencies of discrete responses, 40.64% responded "Yes-Yes" for both the first and second bids, 23.50% responded "Yes-No", 23.11% responded "No-Yes", and the remaining 12.75% responded "No-No" for both bids.

3.2. Users' Mean Willingness to Pay for Improved Irrigation Water

Before presenting the regression results from the Bivariate Probit model, first testing of whether Bivariate Probit is a better fit than Univariate Probit model by performing a Wald test by considering whether the correlation coefficient (ρ) between the two error terms is zero, or not is made. The Wald test suggests that, the estimate correlation coefficient is statistically and significantly different from zero at 1% level of significance. This indicating that the null hypothesis that two equations are independent is rejected at 1% level of significance for both equations. The estimated correlations coefficient is 0.98, it means that the two variables are essentially positively correlated that means unobservable determinants together. As such, the two variables (errors) are correlated and the probability of one variable will be dependent on the probability of the other. Wald $chi^2(2)$ = 215.67 at 1% level of significance indicating that goodness-of-fit under the null hypothesis that all parameters are zero can be rejected. Hence, our data fits the bivariate probit model very well. The regression output (Table 2) also revealed that the coefficients of both the initial and follow-up (second-bid values) are negatively and significant at 1% probability level. The implication of this negative relationship indicates that, as the value of the initial and second price increases, households' WTP for the improved irrigation water use decreases.

The parametric WTP estimates are used to estimate the mean WTP and the respective confidence intervals, and employ the method introduced by Krinsky and Robb (1986), which was found to be robust, particularly for small to medium sample sizes (Claudy *et al*., 2011). The estimated mean WTP and the confidence intervals from both equations are presented in Table 3.

As shown in Table 3, the result indicates that the point estimate of the mean willingness to pay for the improved irrigation water use for equation one and two are Birr 575.23 and Birr 718.78 per year per *timad* (0.25

ha), respectively. Alemayehu (2014) reported comparable reasons and mentioned the fact that the second equation parameters are likely to contain more noise in terms of anchoring bias as the respondent is assumed to take the clue from the first bid while forming his/her WTP for the second question, and estimates from the first equation are generally used in computing mean WTP. Thus, 575.23 Birr per year per *timad* (0.25 ha) estimated from the first equation was used in this study to estimate the mean WTP, if the scenario of improving irrigation use is implemented in the study area. On the other hand, the mean WTP from open ended question is estimated to be 562.25 Birr per year per 0.25 ha. As a matter of fact that households become free riders in the open ended questions, the mean willingness to pay in double-bounded dichotomous choice format is higher than that of open-ended CVM when their means are compared. This is in agreement with the finding of (Anteneh, 2016).

3.3. Estimating Aggregate Willingness to Pay

The aggregate willingness to pay for year round supply of improved irrigation water can be estimated by taking the total number of beneficiary households in the command area. According to WWIDAO (2016), the total number of beneficiary households is estimated at about 2701 and the total irrigable area is about 10,777 ha. Based on these figures, the expected aggregate willingness to pay for irrigation water supply using the double bounded and open ended question is Birr 24,797,015 and 24,237,473, respectively.

3.4. Estimated Demand for the Improved Irrigation Water

This relationship can be more easily observed by deriving a demand curve for the improved irrigation water use. To this end, one should measure the midpoint of maximum WTP along the vertical axis and the number of households who are willing to pay per *timad* per year along the horizontal axis.

As shown in Figure 1, the demand curve has a negative slope like most economic goods under normal conditions. This implies that increasing the price has a disincentive effect on the demand for improved irrigation water use, ceteris paribus.

4. Summary and conclusion

As scarcity of irrigation water is rising, pricing of agricultural water and cost recovery can play a significant role in promoting water use efficiency. Hence, the main objective of this study was to analyze economic valuation of improved irrigation water use in Woliso District.

The study used both primary and secondary data. The elicitation method used was double bounded format with an open-ended follow up question to elicit farmers' willingness to pay for the improved irrigation water use, and the researcher administered the survey using an in-person interview. Five choice sets, (200, 100, 400), (300, 150, 600), (400, 200, 800), (600, 300, 1200) and (700, 350, 1400) were also provided to each respondent for the choice experiment part to determine their WTP for improved irrigation water use.

In this study, Seemingly Unrelated Bivariate Probit model was used to estimate the mean WTP of farmers for improved irrigation water use. Then, mean willingness to pay from the dichotomous choice questions were computed using the Krinsky Robb method. Therefore, the mean willingness to pay for the provision of improved irrigation water from the double bounded dichotomous question was Birr 575.23 per year per *timad* (0.25 ha). On the other hand, the mean willingness to pay from open-ended questions was Birr 562.25 per year per *timad* (0.25 ha). Thus, in this study, the mean willingness to pay from dichotomous choice questions is greater than open-ended questions. The aggregate welfare gain from improved irrigation water use in the study area from the double bounded dichotomous choice format and open ended format was calculated to be 24797015 and 24237473 per year, respectively. The study found that the value of improved irrigation water use from open ended format was relatively underestimated as compared to the double bounded format. This indicates free riding and lack of base for answering WTP questions under open ended format. Thus, in estimating the value of environmental resource like irrigation water at farm household level, it is important to use CVM in the form of double bounded elicitation format than other elicitation method. On the other hand, the estimated aggregate demand for improved irrigation water is similar to the demand of the household to most economic goods under normal conditions which indicates as the payment increases, the number of households willing to pay that amount declines.

In general, the study founds the willing of farmers to pay for improved irrigation water use in the study area. Thus, appropriate valuation of irrigation water will make the user more aware of the resource scarcity, creating more value for the improved irrigation, leading to efficient management of the improved system. Accordingly, farmers are more beneficiary and profitable enterprise.

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Table 1: Frequency of sample households' discrete response

Joint response	Frequency	Percent
NN	32	12.75
NY	58	23.11
YN	59	23.50
YY	102	40.64
Total	251	100.00

Note: YY: Yes-Yes: YN: Yes-No; NY: No-Yes; NN: No-No
Source: Own computation- result based on the 2017 survey data.

Table 2: Parameter estimates of Seemingly Unrelated Bivariate Probit model

Variables	Coefficients	Standard Error	Z-Value
Answer for initial bid			
IBID(Initial bid)	-0.0039872***	0.0004139	-9.63
Constant	2.293553***	0.2283608	10.04
Answer for the second bid			
SBID(second bid)	-0.0025791***	0.0001763	-14.63
Constant	1.853782***	0.1515109	12.24
Rho	0.98	0.0006013	

Number of Observations = 251; Log- likelihood= -252.49891
Wald chi2 (2) = 215.67; Prob > chi2=0. 000
Likelihood-ratio test of rho = 0: chi2 (1) = 25.5935; Prob > chi2 = 0.0000
*** Significant at 1% significance level.
Source: Own computation- result based on the 2017 survey data.

Table 3: The estimated mean WTP

Measures	WTP	LB	UB	AS	CI/Mean	Difference
Mean for Equation 1	575.23	531.16	625.72	0.0000	0.16	94.56
Mean for Equation 2	718.78	660.48	775.43	0.0000	0.16	114.95

Where: Achieved Significance Level for testing H0: WTP<=0 vs. H1: WTP>0
LB: Lower bound; UB: Upper bound
Source: Own computation- result based on the 2017 survey data.

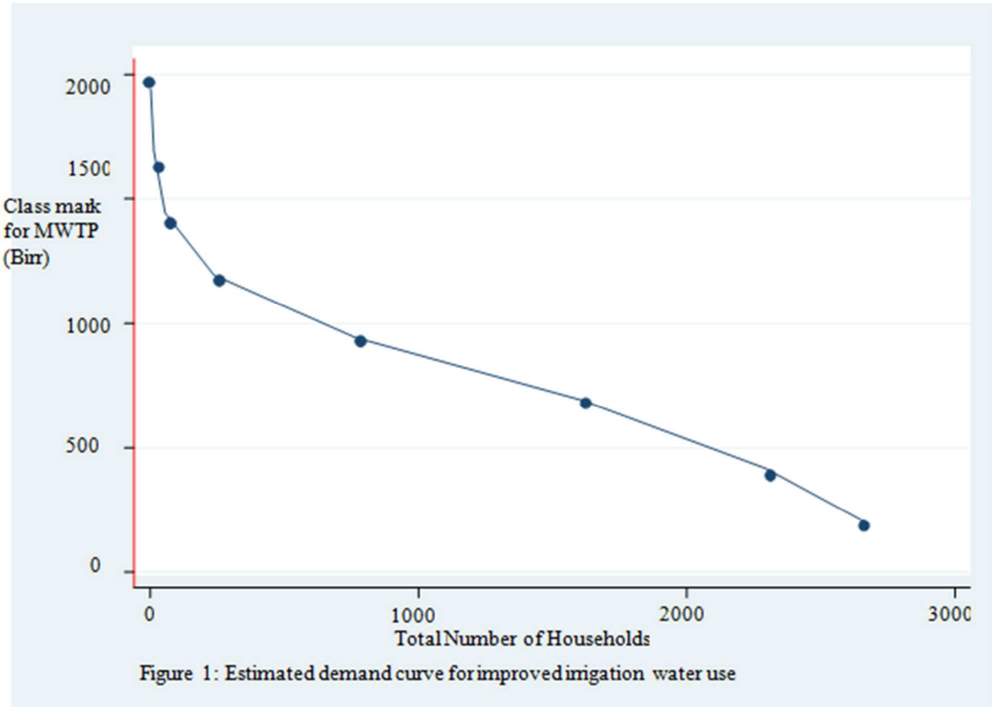

Figure 1: Estimated demand curve for improved irrigation water use

Source: Own design, 2017.