Valuing Non-Agricultural Uses of Irrigation Water: Empirical Evidences from the Abbay River-Basin of the Amhara Regional State, Ethiopia

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Chapter One

Introduction

1.1. Background

Water, which constitutes about 75% of the earth and interestingly about 75% of human body, is a special economic good that has some basic characteristics. Individually, these characteristics may not be restrictive, but in combination they show that water has to be dealt with in a very special way. These basic characteristics include, firstly, water is essential in the sense that there is no life, no economic production, no environment and no human activities without water. This may make water special, but not unique. The same can be said about air, land, fuel and food. Secondly, water is scarce. That is, in many parts of the world, increasing demands for water for irrigation, domestic, industrial and environmental uses have created scarcity and competition for this vital resource. Thirdly, water is fugitive, i.e., it is gone if not captured and flows if not stored. Fourthly, water is bulky and not freely tradable. Since water is too bulky, it is not traded over long distances. Fifthly, water is a system where several processes (infiltration, surface runoff, recharge, seepage, re-infiltration and moisture recycling) are interconnected and interdependent with only one direction of flow: downstream. Sixthly, water is without substitutes. Although other economic goods have alternatives, water has none. For instance, for fuel one can choose between oil, gas, coal, wood, hydropower or solar power (Savenije, 2001).

Globally, approximately 47,000m^3 renewable water has been generated per year from oceans through evaporations of which about 41,000m^3 per year are potentially exploitable. Of the fresh water available for human consumption, we are using about 40-60% (Johansson, 2000). Irrigation accounts for about 70 per cent of all global fresh water use, while industry and domestic uses consume 23 per cent and 8 per cent, respectively (Matsuno et al., 2002 and Jensen et al., 1998). This implies that available fresh water is used for agricultural and non-agricultural purposes.

Although primary purposes of irrigation systems are supplying water at the appropriate time and quantity to agricultural sector in order to insure food security particularly in rural areas of low-income countries, these systems also provide water for a wide variety of less documented non-agricultural uses. The term non-agricultural use and non-crop use of irrigation water are used interchangeably in this study. According to Meinzen-Dick and Jackson (1997), non-agricultural uses of irrigation water can be seen as consumptive purposes such as gardening, drinking water, livestock watering, fodder production and construction, and non-consumptive uses including washing, bathing, fishing, and religious and recreational uses. The pressure on irrigation water for non-crop purposes is higher in situations where it is difficult, expensive or even impossible to develop new water supply systems for domestic uses. In arid and semiarid parts of the world, especially the developing countries water from irrigation systems is the sole source for domestic uses such as drinking, washing and other related purposes (Boelee and Laamrani, 2004).

1.2. Statement of the Problem

Ethiopia is the water tower of north-eastern Africa with surface annual run off of 122 billion m^3. The three largest rivers, namely, Abbay, Bako-Akobo and Omo-Gibe account for about 76% of this total annual run off water. The country has also an estimated ground water potential of 2.6 billion m^3, which is equivalent to 1,9424m^2 per capita. Land suitable for irrigation is estimated to be 10 million ha, of which only 200,000 ha (5% of the potential) is currently utilized. The country's hydropower potential, which is 650TWH per year, stands second in Africa next to Democratic Republic of Congo (DRC) (MoWR, 2002 and FDRE, 2002a).

However, by the degree of water withdrawal in relation to water availability, water is economically a scarce resource in Ethiopia, i.e. it has only made use of about 3% of its available water resources, especially in the area of agriculture (irrigation). The limited water withdrawal has created a significant social, economic, environmental and political crisis in the country mainly due to absence of infrastructure, organizational set up, policies and legislations that provide different services of water for different users at the required quality, quantity, time and location. Some of the problems are, on average, 6 million people are exposed to recurrent drought annually including the surplus producing areas; vulnerability of agricultural sector to drought. For instance, the 1984/85 depression, where real value-added in the sector declined by

20% and real GDP fell by over 9% (the worst during the last four decades) is mainly due to shortage of rainfall. Similarly, in 1997/98 and 2002/03, agricultural growth per year declined by 11.2% and 12.2%, respectively, as a result of drought (MoFED and NBE data base); diseases caused by water related problems accounts for 70% of the national diseases; 25% of the livestock of the country are lost due to drought each year; 40% and 75% of the urban and rural population does not have access to clean drinking water, respectively, and 90% of the population does not have access to electricity (FDRE, 2002 and MoWR, 2002).

Thus, one of the paradoxical facts of Ethiopia is that on the one hand the country is the water tower of north-eastern Africa and on the other hand it is one of the most food insecure and drought affected countries on the planet. This situation is not only due to high dependence on nature particularly rain-fed agriculture (i.e., lack of investment in irrigated agriculture) but also lack of appropriate technology and water institutional regimes that ensure efficient and equitable allocation of water among users and use systems in a sustainable manner.

By realizing this fact, the country has developed a 15-year water development plan, which aims to narrow the current gap between demand and supply by increasing supply. The intention of the plan is to address most of the gaps with in 15 years time (2002 – 2016) through increasing the number of large, medium and small scale new water supply infrastructures, maintenance of the existing structures and introducing efficient water supply technologies. Among the water sectors, agriculture (irrigation) has got due attention because of the national development strategy (Agricultural Development Led Industrialization, ADLI) (MoWR, 2002). Sustainable Development and Poverty Reduction Program (SDPRP) of the country also stressed safe drinking water supply, sanitation, irrigation, hydropower, etc. (FDRE, 2002a). Similarly, the Nile Basin Initiative introduced in 1999 emphasized efficient uses of irrigation water for agricultural sector (Nile Initiative Secretariat, 2001). But both national and regional water development plans have marginalized the multiple uses of irrigation water. The IFAD special country program phase-II, which was implemented in 1999 also primarily deals with small scale irrigation in different regions of the country including Amhara, Oromiya, and Tgiray (FDRE, 2002b). The program also basically ignored non-agricultural uses of irrigation water among small scale farmers where other sources of water for non-crop uses are limited. Hence policy practitioners can not make comprehensive water resource utilization plans and management as non-agricultural uses have been excluded or ignored from both national and regional water development programs.

The quantity of water used for non-agricultural purposes is small relative to total quantity of water diverted for irrigated agriculture, but the former use values of irrigation water are higher in terms of household income, nutrition and health in rural areas (Meinzen-Dick and Bakker, 2001). Thus, the implication here is that estimating economic values of irrigation water based on irrigation output (or crop per drop) essentially leads to underestimation of the total value of irrigation water. Moreover, failure to take into account non-agricultural uses of irrigation water has implications for irrigation water management and assigning water rights, especially as increasing scarcity challenges existing water allocation mechanisms. In this paper the term non-agricultural and non-crop uses of irrigation water are used interchangeably.

1.3. Objectives of the Study

The general objective of this study is to analyze the economic values of multiple uses of irrigation water emphasizing its non-agricultural uses using data from the Abbay (or Blue Nile) Basin of the Amhara Regional State of Ethiopia. The specific objectives of the study are to:

- Elicit willingness-to-pay (WTP) of the rural people for non-agricultural uses of irrigation water using the contingent valuation method (CVM);
- Identify major socio-economic determinants of respondents' WTP for non-crop purposes of irrigation water;
- Examine the impact of institutional setup (or property rights regimes) related to irrigation water uses and land tenure security on the respondents' WTP for non-agricultural uses of irrigation water;
- Identify whether women are more willing to pay for non-agricultural uses of irrigation water compared to men;
- Estimate the demand for non-agricultural uses of irrigation water;

- Draw concluding remarks and policy implications relevant to the existing situations of the country

1.4. Research Questions

- Are rural households in the Blue Nile basin willing to pay for non-agricultural uses of irrigation water?
- What would be the non-agricultural use values of irrigation water?
- What are the key social and economic determinants for willingness-to-pay for non-agricultural uses of irrigation water?
- Do irrigation water institutional regimes and land tenure security have any impact on the respondents' WTP?
- Are women willing to pay more for non-crop uses of irrigation water compared to men?

1.5. Significance of the study

Currently, rural Ethiopia is characterized by chronic food insecurity, lack of access to safe drinking water, water born communicable diseases, low agricultural productivity, low utilization of electricity and high infant mortality, which are very challenging for government, policy makers, non-governmental organizations (NGOs) and the local people themselves. One of the causes of these and related problems are lack of appropriate and comprehensive water use policies and institutional setup that ensure multiple uses of this vital resource (particularly irrigation water) among various uses and users. In this regard, identifying and promoting multiple uses of irrigation water and accordingly valuing its economic uses partly improve allocation of this vital resource among various uses and users. This would enhance the three Millennium Development Goals of halving, by 2015, the number of people without sufficient food and income and the number of people without access to safe water for domestic uses while empowering women. Since non-agricultural uses of irrigation water has important implications on health, income and nutritional status of rural households, enhancing multiple uses of irrigation water improves welfare of these users in all aspects (food, health, cash income, better nutrition, etc.). Clearly defining property rights and creating conducive environment for customary rights helps to avoid conflict among water uses and users. The area requires vigorous studies to make policy implications relevant to the particular situation of the country. In this regard, the findings of the study contribute a lot.

Chapter Two

Literature Survey

2.1. Theoretical Framework

2.1.1. Economic Theory and Environmental Valuations

The theoretical basis of environmental valuation techniques is basically derived from welfare economics, which is built on the utilitarian moral philosophies. Utilitarian moral philosophy was developed by philosophers like David Hume (1711-1776), Jeremy Bentham (1748-1832) and John Stuart Mill (1806-1873). The most completed expression of this moral philosophy was in the Utilitarianism (1863) work of Mill. The central axiom of this moral philosophy is that utility is comparable over time and over individuals. Thus, social welfare is weighted average of utilities enjoyed by all individuals in the relevant society (Perman et al., 1999).

The change in utility due to change in prices, quantities or both leads to a change in welfare of the society. Then, by converting changes in utilities into monetary values, it is possible to calculate welfare changes due to the above reasons.

The starting point is the conventional utility maximization theory, which argues that an individual maximizes utility from consumption of marketed goods and non-marketed environmental goods subject to income level or the budget constraint.

That is, Max. $U^{j} = U(X_{i}, Z)$

$$\text{Subject to: } \sum_{i=1}^{n} X_{i} P_{i} = Y \quad \ldots\ldots(1)$$

Where:

U^j =utility of individual j (j=1, 2, 3,…, m)

X_i=vector of marketed commodities (i=1, 2, 3, …, n)

Z= vector of non-marketed environmental goods

P_i= market price of the i^th^ commodity

Y= income level of individual j in monetary value

Then Lagrangean function of this utility maximization problem may be written as:

$$L = U(X_i, Z) - \lambda(Y - \sum_{i=1}^{n} X_i P_i) \qquad \text{……………………….(2)}$$

Where: λ =the lagrangean multiplier

Then, the first-order necessary conditions of the Lagrangean function (assuming interior solutions) become:

$$\frac{\partial L}{\partial X_i} = \frac{\partial U(X, Z)}{\partial X} - \lambda P_i = 0$$

$$\frac{\partial L}{\partial \lambda} = \sum_{i=1}^{n} X_i P_i - Y = 0 \qquad \text{……………………………(3)}$$

Solving equation (3) for X_i gives us what is known as the Marshallian (or ordinary) demand function, which depends on market price (P_i), money income (Y) and environmental goods (Z). That is,

$$X_i = X(P_i, Y, Z) \qquad \text{…………………………………......(4)}$$

For the Marshallian demand function, the welfare changes due to price changes is given by the area between two price lines bounded by the Marshallian demand curve. This is basically equal to the consumers' surplus (CS), which is defined as:

$$CS = \int_{p_0}^{p_1} X_i(p_i, Z, Y) dP_i \qquad \text{………………………(5)}$$

Now, substituting (4) into $U^j = U(X_i, Z)$ yields the indirect utility function given as follows:

$$V = (P, Y, Z) = U(X(P_i, Y, Z), Z) \quad \text{……………………(6)}$$

The indirect utility function depends on market prices of commodity (X), money income (Y) and environmental commodities (Z).

However, both direct and indirect utilities are unobservable and hence it is impossible to measure welfare change due to price changes based on the utility concepts. Fortunately, there are two basic concepts, namely, the compensation variation (CV) and equivalent variation (EV) to measure welfare change due to price changes. That is, CV and EV are the conventional welfare measures (for the price changes) corresponding to the maximum amount of money an individual would be willing to pay (WTP) to secure the change or the minimum amount he/she would be willing to accept (WTA) to forgo the change (Hanemann, 1991).

Suppose the price of marketed commodity changes from P^0 to P^1. In terms of indirect utility function, the CV and EV measures for this change become:

$$V(P^0, Z, Y) = V(P^1, Z, Y - CV) \quad \text{…………………….(7)}$$

$$V(P^0, Z, Y + EV) = V(P^1, Z, Y) \quad \text{…………………….(8)}$$

The dual problem of the utility maximization in (1) is expenditure minimization.
That is,

$$\text{Min.} \ \sum X_i P_i$$

$$\text{Subject to: } U(X_i, Z) = U \quad \text{…………………………………………(9)}$$

Solving the first-order necessary conditions of the Lagrangean function of the expenditure minimization problem yields the demand function known as Hicksian (or compensated) demand function, which may take the form:

$$h_i = h(P, Z, U) \qquad \text{……………………………………….(10)}$$

And expenditure function of the form:

$$e(P, Z, U) = \sum_{i=1}^{n} P_i h(P, Z, U) \qquad \text{…………………….(11)}$$

Then, in terms of the expenditure function, the CV and EV can be defined as:

$$CV = e(P^0, Z, U^0) - e(P^1, Z, U^0) \qquad \text{……………(12)}$$

$$EV = e(P^0, Z, U^1) - e(P^1, Z, U^1) \qquad \text{…………….(13)}$$

Welfare measures can also be defined for changes in quantities of environmental goods. The quantity-constrained nature of the problems implies that consumers can not adjust for quantity changes to satisfy the conventional optimizing conditions of equality of marginal rate of substitution and price ratios. In such a case the appropriate measure of welfare change are compensating surplus (CS) and equivalent surplus (ES) (Freeman, 1993).

By differentiating the indirect utility function in (6) with respect to the environmental goods (Z), it is possible to indicate welfare change due to changes in environmental commodities. That is,

$$\frac{\partial V(P, U, Z)}{\partial Z} = \frac{\partial U(X(P, Y, Z), Z)}{\partial Z} \qquad \text{………………………(14)}$$

$$\Delta U^j = V(P, Y, Z^1) - V(P, Y, Z^0) \qquad \text{………………….(15)}$$

Equation (15) implies changes in welfare of single individual for changes in Z from Z^0 and Z^1 while price and income remain constant at P and Y .For all individuals in the relevant society the welfare changes become:

$$\sum_{j=1}^{m} \Delta U^j = \sum_{i=1}^{n} \left\{ V(P, Y, Z^1) - V(P, Y, Z^0) \right\} \qquad \text{………………..(16)}$$

This implies that the welfare impact of changes in environmental goods is equal to the sum of the individual marginal valuation of that good between Z^0 and Z^1.

Citrus Paribas, change in Z from Z^0 to Z^1 ($Z^1 > Z^0$) leads to change in the indirect utility function from $V^0 = V(P, Z^0, Y)$ to $V^1 = V(P, Z^1, Y)$ ($V^1 > V^0$). Then, the compensating surplus (CS) and equivalent surplus (ES) measures for this change are defined, respectively, as:

$$V(P, Z^1, Y - CS) = V(P, Z^0, Y) \quad \text{……………………..(17)}$$

$$V(P, Z^1, Y) = V(P, Z^0, Y + ES) \quad \text{………………………(18)}$$

It is also possible to define the CS and ES in terms of the expenditure function as:

$$CS = e(P, Z^0, U^0) - e(P, Z^1, U^0) \quad \text{………………..(19)}$$

$$ES = e(P, Z^0, U^1) - e(P, Z^1, U^1) \quad \text{…………………(20)}$$

Therefore, CS due to change in environmental goods (Z) measures the maximum amount of money that individuals are willing to pay to secure any positive change in Z while ES measures the minimum amount of money individuals are willing to accept in compensation for any reduction in environmental quantities, qualities, or both.

2.1.2. Methods of Environmental Valuation: Direct and Indirect Approaches

Over the past few decades, several valuation methods have been developed to analyze the types of economic values associated with environmental and natural resources (see Hanemann, 1994). These valuation methods can generally be classified into two groups, namely, direct and indirect methods.

2.1.2.1. Direct Methods of Environmental Valuation

The direct approach (or stated or expressed preference method) refers to the direct expression of individuals' willingness to pay or willingness to accept in compensation for any change in environmental quantities, qualities, or both. That is, direct valuation method involves direct estimation of environmental value based on the responses of individuals to the hypothetical valuation questions and hence it does not depend on market information (Freeman, 1993). The typical example of direct valuation method is the contingent valuation method (CVM).

The contingent valuation method (CVM) involves the use of sample surveys (questionnaires) in order to elicit the willingness of respondents to pay (generally) for hypothetical projects or programs. The name of the method refers to the fact that the values stated by respondents are contingent upon the constructed (or hypothetical) market presented to respondents (Portney, 1994). Mitchell and Carson (1989) also defined the CVM as a survey technique that attempts to elicit information about individual preferences for a good or service by directly asking individuals questions on how much they value the good or service. For Freeman (1993) contingent valuation is the method that involves the direct expression of values by respondents and could be interpreted as measures of compensating variations.

In the contingent valuation method, respondents are asked various questions on the basic issues such as the maximum amount they are willing to pay (WTP) to access and enjoy any welfare gain due to an improvement in environmental quantities, qualities or both or the minimum amount they are willing to accept (WTA) in compensation for welfare loss due to deterioration in environmental quantities or qualities or both. The basic idea of the contingent valuation method is that in the hypothetical market it provides a means of deriving values when they are not observed in the real market i.e., when values can not be obtained in more traditional ways (Tietenberg, 2003).

The history of the CVM can be traced back to 1940s when Ciriacy-Wantrup (1947) wrote about benefits obtained from preventing soil erosion, conserving some biodiversity and reducing siltation of streams by directly asking individuals for their maximum WTP. Unfortunately, he did not attempt to use it. Almost after two decades it was Davis (1963) who applied the contingent valuation method in academic research for the first time where he tried to estimate the value to hunters and wilderness lovers of a particular recreational site. Since then particularly in 1970s researchers in natural and environmental economics have made increasing uses of the CVM in order to value non-marketable natural resources. In the mid 1990s a bibliography lists 1,600 studies and papers using the CVM from over 40 countries on several topics including sanitation, health, environment, transportation and education (Hanemann, 1994 and Portney, 1994).

However, studies using the CVM formed a sort of academic industry and only in the late 1980s that contingent valuation studies began to receive the kind of scrutiny normally devoted to the evidence in high-stakes legal proceedings (Portney, 1994).

CV surveys entail three operations, namely, designing a questionnaire, conducting a survey, and analyzing the survey results (Kaliba et al., 2003). Although there is no standard approach in designing the contingent valuation surveys, the following basic components must be there. Firstly, the surveys must contain a detailed description of the situations respondents are being asked to value. Secondly, the surveys must have mechanisms for eliciting value from the respondent. These mechanisms can take several forms including open-ended questions, biding games, payment card and single bounded and double bounded referendum formats. Thirdly, contingent valuation surveys usually elicit information on the socio-economic characteristics of the respondents such as age, sex, income level, education, marital status, and family size (Christe and Schuwab, 1995 and Portney, 1994).

Since the 1970s many researchers have employed the CVM due to its basic advantages over other methods of valuation. Firstly, it captures both use values and non-use values and hence it is more comprehensive. Secondly, the CVM yields compensated or an equivalent income consumer surplus from the Hicksian (or compensated) demand function whereas the travel cost method and hedonic pricing method, which depend on the actual market value of related market commodities lead to the Marshallian demand function.

Although a number of researchers have employed the CVM, using such survey method has some basic problems in the sense that survey respondents could give biased information. The four major potential biases in the contingent valuation surveys are: strategic bias, starting point bias, hypothetical bias and information bias (Tietenberg, 2003).

The basic idea of the strategic bias is that a respondent or groups of respondents may give biased information (answer) to influence a particular outcome. Such information may not reflect the actual value of the resource being valued.

The concept of starting point bias refers to survey instruments in which respondents are asked to check of their answers from a predefined range of possibilities. The problem here is that how the survey questionnaire is designed may affect the resulting answers.

As the name indicates, in the hypothetical survey questionnaires, respondents are confronted by an artificial set of alternatives rather than actual choices. Since the respondents are not actually expected to pay the estimated values, the respondents may treat the survey as providing ill-considered answers. Studies in the literature tried to compare WTP estimated based on the hypothetical survey with actual expenditure and some reported that estimated value from the WTP survey results are higher than the actual expenditure while majority of the studies found that the differences are not statistically significant (Hanemann, 1994).

The problem of information bias may arise in the situation where respondents are asked to value attributes with which they have no or little experiences. Thus, if respondents have no experiences about attributes of resources they are asked to value, the valuation will be based on an entirely false perception.

2.2.1.2. Indirect Method of Environmental Valuation

The indirect (inferential) approach (or revealed preference method) involves inferring about the unobservable demand for and hence value of the environmental goods and services based on the observable demands for the related marketable goods and services. That is, using information on market transactions for related private goods and services, economists try to infer the demand for environmental goods and services (Freeman, 1993 and Tietenberg, 2003). The indirect methods include travel cost method (TCM), hedonic pricing method (HPM) and averting expenditures.

The basic idea of TCM is that it infers the value of a recreational site (such as parks and lakes) using information on the amount of money and time individuals spent to enjoy that site. Thus, it measures value of environmental resources based on actual (or observed) preferences. However, the main drawback of this method is that it ignores non-use values of environmental resources (Tietenberg, 2003).

Hedonic pricing (HP) derives from characteristics theory of value and it has been mostly applied to analyze the underlying demands for and supplies of characteristics of housing such as age, size and number of rooms and neighborhood characteristics like air quality, crimes rate and availability of public goods (e.g. roads) (Palmquist, 1984). In recent years, the HPM is applied to the wider areas such as agricultural land, land rents, effects of climatic conditions on agriculture, urban land, etc. (Kolstad, 2000).

However, there are a number of problems that beset the HPM. Firstly, if consumers are not well informed about attributes of the good being valued, HP estimates are of little relevant. Secondly, it imposes strong assumptions concerning separability of consumers' utility functions. Thirdly, it suffers from econometric pitfalls such as identification problems, endogeneity problems, non-linearity and functional form (Palmquist, 1984).

In the study we employ the CVM to elicit consumers, WTP for non-agricultural uses of irrigation water. The main reason is that the market doesn't exist for non-crop uses of irrigation water. Thus, it is impossible to get such use values based on market information. Besides, indirect methods are inappropriate as they need existence of markets for related goods to infer values of environmental goods.

2.2. Empirical Review

2.2.1. Multiple Uses of Irrigation Water: Country Experience

In developing countries, irrigated agriculture has consumed the largest share of fresh water, accounting over 80% of water withdrawals (Boelee, Laamrani and Van der Hoek, 2000). The primary purpose of irrigation systems is to produce field crops (i.e., water for agricultural uses). However, in low-income countries where modern sources of water supply is limited, irrigation systems supply water for a large number of non-crops production uses including drinking water, livestock watering, gardening, fishing, construction, washing, religious ceremonies, recreational uses and maintaining biodiversity. Sometimes in semiarid areas of developing countries irrigation systems may be the only possible source of water to fulfill the domestic water needs of households. (Bakker et al., 1999, Boelee et al., 2000, Meinzen-Dick and Bakker, 2001, Van der Hoek et al., 2001, Renwick, 2001, Van der Hoek et al., 2002, Van der Hoek, Boelee and Konradsen, 2002, and Boelee and Laamrani, 2004).

Modern water supply systems, which are implemented with the help of water and sanitation experts and aimed at providing pure drinking water of limited amount (about 25-50 liters per capita per day) also, provide water for productive activities like small-scale enterprises. This may lead to the over-use of water from such systems and hence often leads to the breakdown of the systems (Penning de Vries et al., 2003). This implies that water systems (irrigation or modern drinking water systems) have multiple purposes (i.e., have uses outside the domain of their primary purposes).This multiple use of water is recognized by indigenous water supply systems.

An estimate indicates that in developing economies the demand for non-agricultural uses of water has been increasing faster (even 100%) between 1995-2025 due to population growth, urbanization, and economic expansion (Southeast Asian countries) in the face of growing water scarcity, which has been worsened by severe constraints on the supply side. The constraints include: limited sources particularly in dry areas of North Africa, West Asia and northwest India and economic constraints that slow development of new water supply systems (Rostgrunt, 2000).

Although the amount of irrigation water used for non-agricultural purposes is small compared to the amount used for field crops, use values are high in terms of household income, nutrition and health in rural area (Meinzen–Dick and Bakker, 2001). Therefore, non-agricultural uses of irrigation water have important implications in irrigation water management and assigning water rights particularly in face of growing scarcity of water resources. However, non-agricultural uses and users of irrigation water are ignored in developing water resources policies. That is, multiple needs of irrigation water have rarely been taken as a starting point in designing irrigation water systems. One manifestation of this is that most agents dealing with water resources have only sectoral policies (i.e., either irrigation water or drinking water or water for environmental uses) separately. Thus, there are no policies that promote multiple uses of irrigation water. In other words, although a government has overall water development policies and strategies, the implementing bodies have neither the mandate nor the incentive to balance water resources among various uses and users (Meinzen–Dick and Bakker, 2001, Yoder, 1983).

2.2.1.1. The Asian Experience

In the dry zone of Sri Lanka with tropical climate where temperature is almost constant ($26c^0$ - $28c^0$) across the year and mean annual rainfall is about 1,000mm, irrigation water is directly or indirectly used for domestic purposes (like drinking, cooking, bathing and garden), livestock watering, and fishing but recreational uses of irrigation water is minimal (Bakker, et al., 1999 and Meinzen–Dick and Bakker, 2001).

Meinzen–Dick and Bakker (2001) analyzed a survey of 156 households stratified into old and new irrigation systems in Kirindi Oya region of Sri Lanka based on an interdisciplinary field research. The authors also interviewed concerned government officials, local politicians and representatives of different water user groups in order to derive the implications for water resource management. In this irrigation system the authors identified various uses and users of irrigation water.

Although agriculture is the most important user of water from irrigation systems in the region, irrigation water has been used for homesteads gardens, which are the main sources of vegetables and fruits for home consumption and markets. Water from irrigation systems is also used for domestic uses (drinking, cooking and bathing), livestock and fishing implying that water from Kirindi Oya irrigation systems has multiple uses. Renwick (2001) also reported the multiple uses of irrigation water in the Kirindi Oya irrigation systems. The author tried to estimate economic value of irrigated paddy rice production and reservoir production. For instance, the average net economic return from fisheries is estimated to be $544,000 – $566,000 per year. This result implies the importance of recognizing and assessing the value of irrigation water for non-agricultural uses.

However, water management institutions do not consider such multiple uses of irrigation water in Kirindi Oya irrigation systems. That is, although water rights for agricultural purposes are well-defined, such rights for non-agricultural uses are less recognized or sometimes not recognized particularly in the statutory law, which is almost the case in most developing economies (Meinzen–Dick and Jackson, 1998). Non-agricultural uses of irrigation water are not only ignored by the law but also taking irrigation water for such uses particularly for homesteads is "illegal" in Kirindi Oya due to shortage of irrigation water for agricultural uses (Meinzen–Dick and Bakker, 2001).

Therefore, in designing irrigation water rights and estimating values of irrigation water, it is very important to consider multiple uses and users' rights and uses of water for non-crop purposes as ignoring these use values leads to underestimation of the total economic value of water from irrigation systems.

In the case of China, Daming et al. (2002) discussed water resource policies, institutional capacities and availability of water for agriculture and non-agricultural uses in Yunnan river basin of Yunnan Province of China. The authors reported that even if the province has rich water potential in absolute terms, drinking water for human-beings and livestock is in short supply due to lack of appropriate water infrastructure. This implies that there is a competition for water from this river basin among various uses and users within and without the agricultural sector. Thus, as in the case of many developing countries water from Yunnan river basin provides multi-services for the rural dwellers of the province.

Empirical evidence from northwest India revealed that since groundwater of the area is salty, irrigation canals provide water not only for agricultural purposes but also for non-agricultural uses such as domestic uses, livestock watering, recharging groundwater, wildlife, flora and fauna. This implies that water from irrigation canals has multi-purposes in northwest India. When irrigation water is in short supply, animals use salty groundwater, which reduces milk products by about 50%. Since income from livestock accounts for a significant share of income of rural households, a reduction in milk products has an implication on overall income and nutritional status of the societies (Rogers, et al., 1998).

In estimating economic uses of irrigation water the authors argued for consideration of non-agricultural use values as leaving out such use values could result in a serious underestimation of the total benefits of irrigation water. Total economic value of water can be divided into three, namely, value to users, which basically refers to net value of crop output per m^3 of water; net benefits from indirect uses (or non-agricultural) uses; and net value from return flows such as from water diverted for urban uses, agricultural and industrial uses.

Using data from irrigated agriculture in an arid zone of Haryana in India, Rogers, et al., (1998) estimated agricultural and non-agricultural use values of irrigation water. Agricultural use value defined as net value of output per unit of water input (USD/m^3) was estimated to be \$0.019/m^3. Non-agricultural use value for the same area was estimated to be \$0.01/m^3 for additional benefits to the value of water diverted for irrigation purposes. The authors also estimated agricultural and non-agricultural use values of water from irrigation systems in the Subernarekha river basin in India and found that net value per unit of water input in \$0.027/m^3, which is higher than that of Haryana zone, may be due to climatic variations. Non-agricultural use value is estimated at \$0.01/m^3 implying that estimation of only irrigation use value of water from Subernarekha river basin also underestimates use values of irrigation water.

In the case of Punjab basin in Pakistan Van der Hoek et al. (1999) identified multiple uses of irrigation water by collecting information from 360 households in 24 villages using a stratified random sampling technique. The authors reported that the most important source of water for domestic uses is the village tank (*diggi*), which is filled weekly with water from the irrigation systems. The authors concluded that water from irrigation systems is the only sources of all domestic uses either directly or indirectly. The study also claimed that all households particularly females are willing to pay for improved domestic uses of irrigation water in Punjan basin.

Van der Hoek, et al. (2001) also identified multiple uses of irrigation water by emphasizing health impact of domestic uses of water from irrigation systems using 200 households in ten villages of Punjab in Pakistan over one year. The authors claimed that incidence of water born diseases particularly diarrhea is higher where there is absence of enough piped water and storage facilities, lack of toilet and low level of hygiene. Health related problems have important implications on agricultural productivity of farmers. Therefore, taking into account domestic uses of water from irrigation systems in managing irrigation water could yield essential health benefits for users. Van der Hoek, Feenstra and Konradsen (2002) also reported the same results, especially in the area of integrated irrigation water management, which gives priority for domestic uses of water from irrigation systems.

Matsuno et al (2002) cited various research works on the multiple uses of irrigation water in Taiwan, China, Japan, India, Pakistan and Bangladesh. For instance, using groundwater recharge function, which depends on area of rice, soil infiltration rate and number of irrigation days, the authors analyzed non-agricultural uses of irrigation in Taiwan and reported that the total value of groundwater recharged from the rice fields was estimated at $2.2 million during 2000.

In Japan and Taiwan besides rice production, which is stable food, paddy rice irrigation fields provide environmental services and opportunities for recreational activities (Matsuno, 2002). Using the contingent valuation method, Chen, et al. (2002) investigated the extent to which farmland provides value other than crops production in Taiwan. They claimed that the majority of people in Taiwan have recognized positive externalities of the paddy rice fields and on average each individual is willing to pay about $170 per year in order to maintain water preservation and land protection functions of paddy rice irrigation water. This implies that individuals are willing to pay for non-crop production uses of irrigation water and paddy rice fields.

2.2.1.2. The Latin American Experience

In the case of the Maipo River Basin in Chile, Rosegrant et al. (2000) introduced an integrated economic hydrologic modeling framework that accounts for the interactions between water allocations, farmer input choice, agricultural productivity, nonagricultural water demand, and resource degradation in order to estimate the social and economic gains from improvement in the allocation and efficiency of water use. The authors reported that of the total water withdrawal from the basin, agriculture accounted for 64%, domestic uses for 25%, and industry for the remaining 11%. Competition among the different water users and uses, in particular, agriculture and domestic and industrial water uses is increasing rapidly.

The authors pointed out that although the quantity of irrigation water diverted to the agricultural sector is large, its value is small. The authors further argued that introducing trading with water will create incentives to move water from lower valued agricultural products to higher valued agricultural outputs and non-agricultural uses. The idea here is that farmers can gain more benefits if they sell their water rights (assuming that water rights are well-defined) to municipal and industrial uses during months of little or no crop production. The basic implications are that irrigation water has multiple-uses and urban dwellers (like the rural societies) are willing to pay for domestic uses of irrigation water. Introducing pricing in water uses may also lead to efficient allocation of this vital resource.

2.2.1.3. The African Experience

An estimate indicates that all African countries will be physically or economically water scarce by the year 2025. South and North African countries are among the nations that will face physical water scarcity and hence they may not meet their projected water needs in 2025. For instance, in Egypt during 1997 water requirement and availability was $59*10^9$ m^3 and $60*10^9 m^3$, respectively, but during 2025 the projection indicates that water requirement will rise to $81*10^9$ m^3 while availability will remain at $60*10^9$ m^3 implying a deficit of $21*10^9 m^3$ (Gad, 2000).

Economically water scarce countries like Ethiopia have high potential of water resources but they are not in a position to make additional investment in water sector development due to shortage of capital and do not encourage institutional set up that leads to efficient and equitable water allocation among various uses and users (Inocencio et al., 2003).

In Africa where the majority of its citizens are food insecured, priority is given to production of enough food at national and household levels using both rainfed and irrigated agriculture. Thus most African countries including Ethiopia have emphasized irrigation water for agricultural purposes in their programs of food self-sufficiency. This implies that multiple uses of irrigation water particularly its non-agricultural uses have not been given enough attention or at times have been ignored by the concerned bodies. But it is clear that in dry areas of African countries agricultural water has been used for non-agricultural purposes such as domestic uses, livestock water, etc.

A case study in semi-arid Zaio in northeast Morocco where average annual rainfall is 230mm reveals that in addition to its primary purposes of crop production, irrigation water plays a crucial role in fulfilling basic human needs for water such as drinking, bathing and cooking, watering livestock, making bricks, etc. In this area agriculture and livestock (particularly sheep and goats) are the major sources of income. Thus, since irrigation systems provide water for livestock, which are the main sources of income, the multiple uses of irrigation water have contributed to income and nutrition of Zaio region (Boelee and Laamrani, 2004).

Macgregor et al. (2000) attempted to estimate agricultural uses of water in the Stampiet area in Namibia using the residual imputation model developed by Young (1996). The country gets its water supplies from three major sources, namely, ground water (about 50% of country's water supply), the perennial border rivers and the internal ephemeral rivers. The authors estimated economic value of water for agricultural uses, which has consumed about 65% of total water supply of the county and reported an economic water value of 0.64 Namibian dollars per meter cubic. The study did not consider economic value of non-agricultural use of irrigation water, which has consumed the remaining 35% of water supply. Therefore, economic value of water reported in this study seriously underestimates total economic value from the water supply systems in Stampriet area.

Tanzania with a population of 34 million (80% of whom depends on agriculture) has abundant physical water resources particularly on its coastal and highland areas, which have received over 1,0000mm rainfall per year.

However, the country is economically water scarce to overcome extreme temporal and special variability in rainfall. The country has utilized small portions of its irrigation potential particularly in the Rufiji and Pangani basins. Irrigation water from these basins is not only used for crop production but also used for non-crop productions such as domestic uses, hydropower supply, livestock watering and fishing (Koppen et al., 2004).

2.2.2. Water Related CVM Empirical Studies

Since the pioneer work of Davis in 1963, a number of researchers in various fields of studies have extensively applied the CVM mainly in developed economies including sanitation, health, environment, transportation and education (Hanemann, 1994).

However, using the CV survey studies in developing countries is relatively a new phenomenon. Whittington (1998) argued that during the late 1980s very rudimentary CV studies were conducted in developing economies. The conventional wisdom at that time was that posing hypothetical questions to illiterate and low income individuals were assumed to be so overwhelming and one should not even try. But today a number of CV studies are reported using data collected from respondents in developing countries. This implies that in recent years CVM has been extensively applied in both developed and developing countries to the valuation of a wide range of environmental goods and services (Venkatachalam, 2004).

2.2.2.1. Developing Countries Experiences

The CVM has been successfully applied to a variety of water related issues including sanitation, water supply, in-stream and off-stream recreation, flow enhancement and health risks. It has also been used in different contextual frameworks like lakes and rivers, groundwater, bathing water, fishing sites, urban water parks, wetlands and marine and coastal areas (Day and Mourato, 1998).

One of the early CV studies carried out by Whittington et al. (1990) estimated individuals' WTP for improved water services in rural areas of southern Haiti using the ordered probit model. The study concluded that WTP of individual respondents is affected by household wealth, education level of respondents, distance of the household from the existing water sources, quality of water and sex of respondents (female). Another early CV study was conducted by Briscoe et al. (1990) in rural areas of Brazil to examine users' WTP for improved rural water supplies and it concluded that tariff for yard taps can be increased substantially (i.e., consumers are willing to pay for improved rural water supply).

Whittington et al. (1991) employed revealed preference and stated preference method to examine demand for rural water for domestic uses in Ontisha in Nigeria. The stated preference method used CVM to estimate respondents' WTP for improved water supplies. The CV survey study results based on data collected from 235 households seemed consistent with the data obtained from private water vending. This implies that the CV study results are sufficiently accurate to be used by policy makers.

In rural area of Punjab in Pakistan Altaf et al. (1992) conducted a CV study with the main objective of identifying determinants of households' WTP for improved rural water supply and comparing the CV study results with market-based results. The authors found that wealth and education of respondents are among the major factors that affect their WTP for improved rural water services. Empirical results of the study also confirmed that the CV study results seem consistent with revealed preference results.

Day and Mourato (1998) estimated value of water quality improvement in the Beijing Metropolitan local rivers using the CVM survey analysis. A carefully designed contingent valuation questionnaire was administered to a random sample of 999 people in the Beijing area. The study reported that annual average WTP per household to maintain water quality in all rivers in Beijing Metropolitan region was estimated to be US $22.

Calkins et al. (2002) estimated WTP of sixty-two households for improved drinking water delivery systems in semi-urban area of Douentza in Mali using linear regression model and a logit model. The later model helps to explain the decision to purchase water or not. The authors asserted that wealth, relative distance to the planned new sources compared to the best existing sources, land tenure security and family size are major determinants of respondents' WTP. The study reported that land tenure insecurity is positively related to WTP implying that tenure insecurity discourages construction of one's own well and hence households tend to pay more for public water sources.

Using multinomial logit model Kaliba et al. (2003) estimated WTP of households' from 30 villages in two regions of Central Tanzania to improve community-based rural water utilities. The study reported that households in both regions are willing to pay the fee, which is higher than the existing tariff charges. WTP is affected by respondents' socio-economic factors like age, wealth and household size. More specifically, WTP for improved water services is negatively affected by age and wealth as older individuals are not directly involved in water fetching and wealthier households have their own water sources or they delegate others to collect water for them at lower costs. The family size is positively related to WTP as households with larger family need more water and hence they are willing to pay more.

The CV study conducted by SANREM CRSP (2003) tried to analyze factors that affect WTP of local communities for improved performance of portal and irrigation water systems through watershed conservation by taking 80 individuals from Cotacachi area in Ecuador. Half of the sampled individuals have access to water from irrigation systems for crop production and non-crop production purposes. The study reported that local individuals in the study area are willing pay to for the improvement in quantity and quality of the drinking water from irrigation water and other sources. The study also argued that the maximum WTP of the society is positively associated with two important factors, namely, respondents' income level and family size. That is, individuals with higher income were willing to pay more for improved quality and reliability of drinking water. The explanation for family size is that households with higher family size will need more and reliable (with better quality) water supply and hence are willing to pay more.

Farrington (2003) also employed the CVM to investigate factors influencing respondents' WTP decisions for improved rural water supply in Tanzania. Findings of the study suggest that decisions to pay for improved water supply for domestic uses are affected by a vector of variables including social and economic factors, perceptions and attitudes towards water quality and personal experiences.

2.2.2.2. The Ethiopian Experience

The Ethiopian experience reveals that limited CVM studies mostly in academic areas have been conducted to investigate factors that influence households' willingness to pay for improved water supply in rural and urban areas including Addis Ababa. There is only one academic research that estimated WTP for irrigation water for agricultural purposes (not for domestic uses) in Tigray Regional State of Ethiopia.

Using the CVM, Fissiha (1997) examined households' WTP for piped water supply in Meki town in Ethiopia. The study reported that more than 50% of sampled households are willing to pay almost twice the existing tariff rates for improved water services. Another CV study by Dunfa (1998) estimated respondents' WTP for improved water supply in Ada'a Liben district of central Ethiopia using data collected from 228 sampled households. The author claimed that households' WTP for rural water supply is related to a number of explanatory variables such as income, availability of credit, distance from the existing water sources and quality of water for domestic uses.

The CVM study by Genanew (1999) for 270 sampled households in Harar town tried to identify determinants of households' WTP and demand for improved water supply using both OLS and ordered probit models. The study found that WTP of households for the required purposes is affected by various factors including income, education level, sex of the respondent and quality of water. The author further reported that mean WTP is about 15 times higher than the existing service charges.

However, all these studies did not consider water from irrigation systems for non-crop purposes as some of them were conducted in urban or semi-urban areas of the country where irrigation is not practiced.

2.2.3. CVM Empirical Studies on Other Resources: the Ethiopian Experiences

Using OLS and ordered probit regression models Tsegabrihan (1999) conducted the CVM study in Tigray Ethiopia for 82 randomly sampled farmers. The study estimated WTP of small holder farmers for irrigation water particularly for small scale irrigation schemes. The survey results are for the main irrigation seasons and the whole year, which depends on the 0.25 hectares of an irrigable land. The study reported that about 90% of respondents are willing to pay up to Birr 600 for the main irrigation system alone. The study further claimed credit availability, education, income and fertilizer supply as the major determinants of respondents' WTP. The study has some limitations. A WTP question to elicit WTP for the 0.25 hectares of irrigable land is not clear whether it asks for the land itself or irrigation water or both. The study also ignores non-crop use values of irrigation water.

Alemu (2000) employed the CVM to analyze households' WTP for community forestry in Ethiopia using tobit model by correcting for sample selection bias in empirical analysis due to invalid responses (protest zeros, outliers and missing bids). The author concluded that income, family size, sex of household head, number of trees owned by respondents and distance of homestead to plantation are the main factors that influence households' WTP for community-forestry in rural Ethiopia.

Tegenge (1999) also applied the CVM to elicit respondents' WTP for environmental protection in terms of cash requirements and time spent (or labor contribution) in Sekota district (Northern Ethiopia) for the sample size of 98 farmers. The study found that about 70% of the sampled farmers are willing to pay zero Birr for environmental protection. However, farmers are willing to spend considerable amount of their time for environmental protection particularly during the slack period. Farmers' willingness to contribute labor for environmental protection is affected by education level, age, sex and households size of respondents'.

Using the CVM study, Tekie (1998) tried to obtain ex-ante valuation of farmers for improved land tenure system in Ethiopia. The study also identified factors that trigger the choice for a positive WTP and the amount farmers are willing to pay for land tenure improvements. The study concluded that farmers are willing to pay for changes in existing tenure arrangements and probability of paying for any institutional change is affected by number of factors like area of land owned by respondents, literacy of household head, non-farm income, number of adult members and mean distance of plots to homestead of the household.

In a nutshell, these and other CVM empirical studies in developing economies in general and Ethiopia in particular on water quality improvement and other non-marketable environmental goods and services imply that the CVM can be successfully applied to low income countries. This invalidates the conventional wisdom, which argues that the CVM could not be applied to developing countries with the majority of illiterate individuals who could not understand hypothetical CVM questions.

Our CV study has three major contributions. Firstly, it is the first in applying the CVM to value non-crop uses of irrigation water (at least in Ethiopia). In this regard its significance and importance is high. Secondly, it adds some empirical knowledge to the limited water related CV studies in Ethiopia. Lastly, it also witnesses the possible application of the CV studies in developing countries.

Chapter Three

Data and Empirical Models

3.1. Data Sources and Types

The primary data utilized in the descriptive and empirical analyses of this study were collected from 260 randomly selected households in two peasant associations (PAs) in Bure districts of West Gojam zone of the Amhara Regional State of Ethiopia from February 5 – March 10, 2005. The data were obtained through CV survey questionnaires that employ face-to-face (or direct personal interview) data collection techniques. Survey questionnaires elicited data on demographic structure of respondents; socio-economic variables such as income, expenditure (on food, non-food & agricultural related activities), education level and wealth of surveyed households; water and land related information particularly on water use rights and security of each right.

Besides the survey contained double-bounded referendum style CV questions in which prices (or bids) on non-crop uses (particularly domestic uses, watering livestock and gardening) of irrigation water were proposed to respondents under existing and hypothetical settings. Prices were proposed for domestic uses of irrigation water, livestock watering and gardening without introducing any change to quantity, quality and reliability of irrigation water under existing rules and regulations that govern irrigation water allocation among various uses and users. The main objective here is to know how farmers (or users) value the existing natural resources (water in this case) without proposing any change (i.e., without any improvement is proposed). Knowing values of existing irrigation water resources helps in formulating policies and strategies that contribute to sustainable and efficient uses of existing resources. Finally, prices were also proposed for domestic uses (drinking and cooking) after a change in quality of irrigation water is undertaken in order to know whether users of irrigation water are willing to pay for the improvement in quality of irrigation water for domestic uses or not.

3.2. Sampling Technique

The study area, Bure district of West Gojam zone of Amhara Regional State of Ethiopia is selected based on various criteria such as geographic location (i.e., inclusion in the Blue Nile river basins), long history of irrigation experiences and different property right regimes (namely traditional communal-water fathers and modern communal-water users associations) that govern irrigation water allocations among users. Time limits us from expanding our survey to other zones of the Amhara Regional State of Ethiopia.

Once the study area is identified, two kebeles (peasant associations) were selected purposively among four major rivers as peasants must be users of irrigation water for multiple purposes (at least in our case) and allocations of irrigation water for crop production is ruled by various property right regimes like water father (WF), water users associations (WUAs) and community based (or open access). These two PAs are stratified into a number of Goths-the lowest administrative units-from which a total of 260 households were selected using simple random sampling. Number of households to be selected from each Goth is determined based on rule of proportional stratification sampling. Thus, the study combines both simple random sampling and stratified sampling to select the sample size of 260 households.

3.3. Designing Survey Questionnaires and Elicitation Format

For most environmental goods, markets fail to exist due to public nature of environmental goods and externalities. In such cases researchers have developed hypothetical markets in which they elicit from consumers or potential consumers their WTP/WTA on a change in quality, quantity or both of environmental goods.

Designing CV survey questionnaires usually includes detailed description of the good under consideration and its possible substitutes and hypothetical circumstances under which the good is made available to users; questions that elicit WTP/WTA of the respondents for a proposed change and respondents' socio-economic and other basic variables.

CV survey questionnaires of this study have seven different parts. The first two sections provide general information and detailed description of the program followed by the third and fourth parts that try to collect information on demographic structure and education level of respondents and water related data, respectively. The fifth section elicits consumers' WTP for non-crop uses of irrigation water. The last two parts are devoted to pursue information on income, wealth and expenditure and land related indicators (see the annex).

Generally, there are four types of value elicitation formats, namely, open-ended; bidding game; payment card and dichotomous or discrete choice formats. Each format has its own advantages and disadvantages. Double-bounded CV elicitation format can improve statistical efficiency over single-bounded through a number of ways. First, yes-no and no-yes answer to the initial bid make clear bounds on unobservable true WTP. Second, even though yes-yes or no-no answers do not bound actual WTP, additional questions will sharpen the true WTP and hence there are also efficiency gain. Finally, more questions in double-bounded elicitation format lead to large number of responses so that a given function will be fitted with greater observations (Haab and McConnell, 2002). As a result, this study employs double-bounded referendum style elicitation format.

3.4. Field Work Procedure

In order to generate primary data, which are used in this study, the field survey was undertaken in Bure district of West Gojam zone. Before the final survey was implemented the pilot survey that included 15 households was carried out. The pre-testing pilot survey was conducted after two days intensive training of enumerators so that they could grasp the objective of the survey and detail information in the survey questionnaire.

The main objective of the pilot survey is to set up the starting point price, which are part of the main survey. In the pilot survey, the open-ended election format is employed, which takes the form "What is the maximum amount you are willing to pay for all amount of irrigation water you have used for six months for domestic uses? Livestock? Gardening?" In the pilot survey we also elicit maximum willing to pay for improved irrigation water for domestic uses. The result obtained form the pilot survey varies from zero (protest zeros) to Birr 80.00 for the six months for different uses. The pilot survey also used to modify (i.e., include some ideas) into the survey questionnaire before finalizing it.

Then based on the pilot results five starting point price were introduced and total sampled households were divided randomly into five equal groups (each group with 52 households). The final survey was implemented from 20 February - 10 March 2005 where ten enumerators and one supervisor were participated in the survey after necessary trainings were given to the participants. The field survey was successfully completed with low invalid responses (about 5% protest zeros).

3.5. Empirical Models

3.5.1. The Probit Model

The main objectives of estimating econometric (or parametric) models in WTP survey are to calculate mean WTP and to allow inclusion of respondents' socio-economic factors into WTP functions. Such incorporation of individuals' socio-economic variables into the CV models helps the researcher to gain information on validity and reliability of the CV results and increases confidences in applications of results obtained from the CV empirical analysis (Haab and McConnell, 2002).

Hanemann (1984) developed the basic model to analyze dichotomous responses based on the random utility theory. The central theme of this theory is that although individual knows his/her utility certainly, it has some components which are unobservable from the view of the researcher. As a result, the researcher can only make probability statement about respondent's 'yes' or 'no' responses to the proposed scenario.

Suppose $u_{ij} = u_i(y_j, x_j, \varepsilon_{ij})$ is indirect utility function for ith respondent.

Where: Y_j= j^{th} respondent income

i =1 denotes the final state and i=0 the status quo (or the initial state)

X_i=vector of household characteristics and attributes of a given choice

ε_{ij} =random components of the given indirect utility

Now, if a payment (also called initial bid, β_i*) is introduced due to changes in a measurable attributes like quality or quantity of environmental goods, the consumer accepts the proposed bid only if

$$u_{1j}(y_j - \beta_i^*, x_j, \varepsilon_{1j}) > u_{0j}(y_j, x_j, \varepsilon_{0j})$$

For the researcher, however, the random components of preferences can not be known and s/he can only make probability statement of 'yes' or 'no' responses. Thus, the probability that the respondent says 'yes' is the probability that s/he thinks that s/he is better off in the proposed program. For individual i, the probability is

$$P(yes) = [u_{1j}(y_j - \beta_i^*, x_j, \varepsilon_{1j}) > u_{0j}(y_j, x_j, \varepsilon_{0j})].$$

This probability statement provides an intuitive basis to analyze binary responses.

For dichotomous (yes/no) responses to the initial bid (β_i*) (i.e., when responses are discrete) neither the multiple linear regression model nor tobit model is appropriate to estimate WTP function. In such a case (i.e., in the case of a dichotomous dependent variable) the probit model better fits the problem at hand.

The probit model can be defined as:

$$\mathbf{T_i = \beta' X_i + \varepsilon_i}$$

$\mathbf{T_i}$ = unobservable households' actual WTP for non-agricultural uses of irrigation water.

$\mathbf{T_i}$ is simply a latent variable. What we observe is basically a dummy variable $\mathbf{WTP_i}$, which is defined as:

$\mathbf{WTP_i}$ = 1 if $\mathbf{T_i} \geq \beta_i$*

$\mathbf{WTP_i}$ = 0 if $\mathbf{T_i} < \beta_i$*

In the single bound elicitation format, the j^{th} respondent is asked if s/he would be willing to pay the initial "bid", β_i*, to get, say, a given improvement in environmental quality, quantity or both. The probability of a "yes" response, or a "no" response, $p_i^{Y\ or\ N}(\beta_i^*)$, can be cast in terms of a random utility maximizing chosen by the respondent. It is clear from the random utility framework that the individual's WTP is a random variable from the point of view of the econometric observer. Thus, while the individual knows his/her own maximum WTP, T_i, to the observer it is a random variable with a given cumulative distribution function (cdf) denoted by $G(T_i;\ \boldsymbol{\theta}\ )$ where $\boldsymbol{\theta}$ represents the parameters of this distribution, which are to be estimated on the basis of the responses to the CV survey. Then, following the work of Hanemann (1984), the response probabilities related to the underlying WTP distribution are:

$$p^Y \equiv p\left\{yes\ to\ \beta_i^*\right\} \equiv p\left\{\beta_i^* \leq T_i\right\} = G(\beta_i^*;\theta)$$

$$p^N \equiv p\left\{no\ to\ \beta_i^*\right\} \equiv p\left\{\beta_i^* > T_i\right\} = 1 - G(\beta_i^*;\theta)$$

The resulting log-likelihood function for the responses to a CV survey using the SB format is:

$$\ln L(\theta) = \sum\left\{d_i^Y \ln G(\beta_i^*;\theta) + d_i^N \ln\left[1 - G(\beta_i^*;\theta)\right]\right\}$$

Where: d_i^Y = 1 if the i^{th} response is Yes and 0 otherwise, while d_i^N =1 if the i^{th} response is No and 0 otherwise.

3.5.2. Bivariate Probit Model

The double bounded (or bivariate) CV model was first proposed by Hanemann (1985) and applied by Hanemann, Loomis and Kanninen (1991) with the main aim to show how the statistical efficiency of single-bounded dichotomous choice pioneered by Bishop and Heberlien can be improved by asking respondents farther questions with higher or lower bid based on the responses to the initial bids.

According to Greene (1997), bivariate probit model can assume the following general form:

$$T_1^* = \beta_1' x_1 + \varepsilon_1$$

$$T_2^* = \beta_2' x_2 + \varepsilon_2$$

$$E(\varepsilon_1) = E(\varepsilon_2) = 0$$

$$Var(\varepsilon_1) = Var(\varepsilon_2) = 1$$

$Cov(\varepsilon_1, \varepsilon_2) = \rho$. This implies that disturbance terms of these equations are correlated in the same spirit as the seemingly unrelated regression models.

Where: $\mathbf{T_1}^*$= j^{th} respondent actual unobservable WTP at the moment the first question is

posed. WTP=1 if $\mathbf{T_1}^* \geq \beta_i^0$ (initial bid), 0 otherwise

$\mathbf{T_2}^*$= j^{th} respondent implicit underlying point estimate at the time of the second

bid is posed.

The double bounded (DB) format starts with an initial bid, β_i^0. If the respondent answers Yes, s/he receives a follow-up bid $\beta_i^u > \beta_i^0$; if s/he answers No, s/he receives a follow-up bid $\beta_i^l < \beta_i^0$. Thus, there are four possible outcomes: (Yes, Yes), (Yes, No), (No, Yes), and (No, No). In terms of the random utility maximizing model given above, the corresponding response probabilities are:

$$p^{YY} = p(\beta_i^u \leq T_i) \equiv G(\beta_i^u;\theta)$$

$$p^{YN} \equiv p(\beta_i^0 \leq T_i < \beta_i^u) \equiv G(\beta_i^u;\theta) - G(\beta_i^0;\theta)$$

$$p^{NY} \equiv p(\beta_i^l \leq T_i < \beta_i^0) \equiv G(\beta_i^0;\theta) - G(\beta_i^l;\theta)$$

$$p^{NN} = p(\beta_i^l > T_i) \equiv 1 - G(\beta_i^l;\theta)$$

The log-likelihood function for the responses to a CV survey using the DB format is:

$$\ln L^{DB}(\theta) = \sum \begin{Bmatrix} d_i^{YY} \ln G(\beta_i^u;\theta) + d_i^{YN} \ln\left[G(\beta_i^u;\theta) - G(\beta_i^0;\theta)\right] + \\ d_i^{NY} \ln\left[G(\beta_i^0;\theta) - G(\beta_i^l;\theta)\right] + d_i^{NN} \ln\left[1 - G(\beta_i^l;\theta)\right] \end{Bmatrix}$$

Where d_i^{YY} =1 if the i^{th} response is (Yes, Yes) and 0 otherwise, d_i^{YN} = 1 if the i^{th} response is (Yes, No) and 0 otherwise, d_i^{NY} =1 if the i^{th} response is (No, Yes) and 0 otherwise, d_i^{NN} =1 if the i^{th} response is (No, No) and 0 otherwise.

3.6. Description and Rationale of Explanatory Variables

In this sub-section rationale and explanations of each determinant of WTP included in our empirical models are briefly summarized.

1. Income

As reported by the 1999/2000 household income, consumption and expenditure survey of the Central Statistical Authority (CSA), households usually tend to underestimate their actual income level due to various reasons like fear of income tax incremental. This is actually observed in this survey where average income is Birr 4,729.65 per household per year whereas average annual total expenditure per household is Birr 5,077.15 (see table 5.2). This study utilizes expenditure as proxy for household income to solve the problem of income underestimation. It is expected that households with higher income have more ability to pay and hence respondents' income affects their WTP positively.

2. Age

In most rural areas of developing countries, farmers have a close touch with nature resources like land, forests and water from their childhood. This implies that ages of respondents are equivalent to experiences in using natural resources and as they gained more experiences they are concerned more about these resources in general and water in particular. Therefore, age of a respondent has expected to have positive impact on her/his WTP. But the positive effect has some maximum age limits and hence age-squared negatively affects WTP of the respondents.

3. Sex

Most often females are responsible to fetch water from given sources for domestic uses. Our survey results depict that fetching water for domestic uses is totally the responsibility of females. Thus, it is expected that female-headed households are willing to pay more for domestic uses of irrigation water compared to male-headed households. In most cases, however, female-headed households are relatively poor versus male-headed households. In our cases, for instance, average annual income per household is Birr 4,322.77 for female-headed households, which is, on average Birr 5,252.33 for their male counterpart. This may reduce female-headed households WTP for domestic uses of irrigation water compared to male-headed households.

4. Education

Generally, education widens horizons of an individual. Moreover, educated (or literate) individuals relatively know more about advantages of natural resources in general and irrigation water resources in particular and hence they are concerned more about these resources. This implies that education positively affects respondent's WTP for non-crop uses of irrigation water.

5. Family size

There are two opposing views about the effects of family size on households' WTP for improved rural water supply. One view argues that households with larger family sizes have more labor available to collect water from alternative sources. The other view, which leads to the same conclusion, claims that given limited income of rural households, family with larger members have low income left over to pay for improved irrigation water supply or other natural resources. Therefore, in both cases family size is expected to affect households' WTP for rural water supply negatively. The second view, which is contrary to the first views, argues that households with large family size are concerned more about quality, reliability and quantity of water supply and hence they are willing to pay more. In our case the former two views seem logical as income of the surveyed households is among critical limiting factors.

6. Irrigation Water Management

Outside its primary uses irrigation water in the study area provides multiple services for the nearby farmers. Irrigation water is managed by “water father” (WF), water users associations (WUAs) and community as a whole (i.e., the open access case) particularly to regulate irrigation water allocation for irrigation purposes among users. The former two irrigation water management systems are very important in settling conflicts over this resource among users.

WUAs have relatively strong legal background and clearly defined and written rules and regulations, which could strengthen rights enforcement mechanisms and develop conflict resolving capacity. These associations teach their members and others farmers to create awareness about uses of natural resources in general and irrigation water in particular. Besides WUAs provide different services such as credit services, marketing services and modern farm tools for farmers, which contribute in boosting income level of these farmers. Thus, farmers organized under WUAs are expected to pay more for non-crop uses of irrigation water compared to farmers under the umbrella of traditional water regulating bodies (i.e., water father and open access) where problems of free riders are high and rights enforcement mechanisms are weak.

7. Choices of Water Use Rights

In the study area, farmers have access to irrigation water for multiple purposes under different property right regimes (i.e., WUAs, WF and/or open access). Farmers have also choices among these rights based on their perception towards advantages of each property right regime, their experiences about the success of modern farmers’ associations. But regardless of history of farmers’ associations in Ethiopia, which did not depend on the interest of most farmers (and hence did not successful), households choose WUAs are willing to pay more compared to those who choose WF or community based irrigation water use rights. This is probable due to advantages of WUAs mentioned above and problems related to irrigation water management under WF and open access.

8. Quantity of Irrigation water Consumption

It is obvious that households consume greater amount of irrigation water for non-crop uses are willing to pay more as the payment directly varies with quantity of irrigation water consumed.

9. Distance from Current Sources (in meters)

There is an inverse relationship between distance to fetch water from the existing water sources and WTP for domestic uses of irrigation water. This is due to the fact that as household is far way from water sources, time spent to fetch water is higher that increases opportunity cost of time.

10. Wealth

In rural areas of most developing countries in general and Ethiopia in particular, households that have one or more livestock mainly oxen are considered as wealthier as oxen are the main traction power. Thus, this study takes total value of livestock as wealth indicators. It is clear that wealthier individuals are able to pay more for non-crop uses of irrigation water.

11. Land Tenure

Since farmers in the study area have no water well or other water sources on their own plot of land, land tenure insecurity has no effect on their WTP for water uses. But reduction in the size of farm plot due to rise in population (or family size) is expected to induce farmers to pay more for non-agricultural uses of irrigation water. The intuition behind this fact is that as land size gets smaller and smaller, farmers are enforced to practice intensive farming, which requires higher amount of water. This implies that irrigation water becomes scarce resource that asks for higher prices to access it. Thus, respondents who are feeling reduction in farm plot are willing to pay more compared to the base group (those feeling no change in farm plot).

12. Peasant Associations (Sites)

Farmers in Wan Gedam, one of the peasant associations included in the sample, are exercising intensive farming activities to produce vegetables and fruits that improve their income. In addition some irrigation water users for irrigation purposes are organized under WUAs where leaders of the association teach users to increase their awareness about benefits of irrigation water. As a result, respondent in Wan Gedam are willing to pay higher compared to the reference site (Wondegi peasant association).

13. Quality of water

Our CV survey questions tried to elicit consumers' WTP for domestic uses of irrigation water. The respondents were asked to provide their WTP under two scenarios. Firstly, they were asked to pay for existing water supply. In this case quality of water supply is inversely related to WTP responses (i.e., consumers facing lower irrigation water quality are expected to pay less). Secondly, consumers were asked to pay for domestic uses of irrigation water after quality improvements are proposed. In this case consumers' WTP for improved water is higher for low quality of irrigation water as consumers want to pay more to get improved water.

14. Location

In this study locations of users of irrigation water for multiple purposes are divided into three. First, the upper users, which refers to location of users of irrigation water immediate to the diversion of water from a river. Second, the middle users indicate users of irrigation water next to the upper users down the canal (or river). Lastly, the end (lower) users refer to irrigation water users at the lowest point. As irrigation water moves down from the upper users to the end users, it quality becomes poor and hence the end users are willing to pay less against the upper users for existing irrigation water (without introducing changes) but the opposite is true if changes in the quality of water are to be proposed (taking the upper users as reference group).

15. Starting Point Bid

The higher the starting point bid is the lower number of respondents who accept the initial bid and hence there is an inverse relationship between initial bid and the yes responses to that bid.

Summary descriptions of these explanatory variables are reported in table 4.1 below.

Table 3.1: Descriptive Analysis of Determinants of WTP for Domestic uses of Irrigation Water

Var.	Description	Mean	Std. Dev.	Min	Max
i1	i1=1 if yes to initial bid, 0 otherwise-for existing irrigation water	0.512	0.501	0	1
i1i	i1i=1 if yes to initial bid, 0 otherwise- for improved irrigation water	0.470	0.500	0	1
ibidy	Initial bid for existing irrigation water (in Birr)	44.077*	21.568	10	70
ibidiy	Initial bid for improved irrigation water (in Birr)	66.115	34.438	20	120
lexp	Natural logarithm of annual total expenditure (in Birr)	8.466	0.377	7.07	9.40
val	Total value of all livestock owned by household (in Birr)	2528.10	1929.26	0	9930
dis	Distance from current water sources (in meters)	223.903	178.578	5	1000
age	Age of respondents (in full years)	45.396	13.226	18	82
fsiz	Family size living in one house (in numbers)	5.692	1.978	1	11
fem	Dummy for sex: fem=1 if sex is female, 0 otherwise	0.188	0.392	0	1
s1	Dummy for site: s1=1 if site is Wan Gedem, 0 otherwise	0.542	0.499	0	1
edu1	Dummy for education: edu1=1 if education ≥ grade four, 0 otherwise	0.203	0.4036	0	1
Loc2	Dummy for location: loc2=1 if middle user, 0 otherwise	0.715	0.452	0	1
loc3	Dummy for location: loc3=1 if lower user, 0 otherwise (upper users are our reference group)	0.1384	0.346	0	1
sour2	Dummy for source of water: sour2=1 if respondent uses water from both river and spring, 0 otherwise (if only spring)	0.519	0.501	0	1
agesq	Age-squared of the respondent	2235.07	1279.59	324	6724
qaun	Quantity of water used per day (in jerry can=20-25 litters)	3.017	1.124	0.5	6
ten2	Dummy for land tenure: ten2=1 if farmers anticipate reduction in farm plot due to	0.592	0.492	0	1

	high population growth, 0 otherwise (no change in farm plot is base group)				
ten3	Dummy for land tenure: ten3=1 if farmers anticipate land distribution, 0 otherwise	0.119	0.325	0	1
adm3	Dummy for irrigation water management: adm3=1 if irrigation water is managed by water father, 0 otherwise (WUAs is reference group)	0.611	0.488	0	1
adm4	Dummy: adm4=1 if water is managed my community (open access), 0 otherwise	0.096	0.295	0	1
chr2	Dummy for choice of water use rights: chr2=1 if respondents choose water father, 0 otherwise	0.327	0.470	0	1
chr5	chr5=1 if respondents choose community based water use rights, 0 otherwise (WUAs is base group)	0.427	0.496	0	1
Qual2	Dummy for water quality: qual2=1 if water quality is satisfactory, 0 otherwise	0.558	0.498	0	1
Qual3	qual3=1 if water quality is bad, 0 otherwise (good quality is our reference point)	0.231	0.422	0	1

Source: Summary of sample survey

* 1USD is equivalent to 8.65 Birr at official exchange rate

Chapter Four

Descriptive Analysis, Estimation Results and Discussions

Data collected through CV questions can be analyzed in three different ways. First, the data may be analyzed through descriptive analysis of socio-economic characteristics of surveyed households. Second, by investigating cross-tabulations of households' responses to WTP questions. Finally, econometric models can be employed to examine determinants of WTP responses of sampled households.

Accordingly, this chapter is organized as follows. The first section provides descriptive statistics of the survey results. The second section deals with multivariate analysis of determinants of respondents' WTP for non-crop uses of irrigation water. The last section computes mean WTP, estimation of total WTP and aggregate demand for domestic uses of irrigation water.

4.1. Descriptive Analysis

4.1.1. Overview of the Study Area and Surveyed Households Characteristics

The Amara Regional State with the total population of over 18 million and total land area 17,675,200 hectors (15% of country's land area) is one of the seven regional states of Ethiopia. About 17% of the total land area of the region is potentially cultivatable and 650,700 hectares of land can be irrigable. But according to 1995 (E.C) data only 83,000 (12.7%) of the potential was actual irrigated of which 93% was cultivated through traditional ways. Rain fed agriculture occupied about 6,006,229 ha with output of 87,095,295 quintals during the same year (Plan and Agricultural and Irrigation Department, 1995).

The case study of this search is Bure District, in west Gojam zone of the nine Zones of the region. The District has a total number of 26 Kebeles (22 are rural kebeles) with total population of 164,675 where 22 rural kebeles account for about 85.6% of total population of the district. The capital of Bure Woreda is Bure town which is located on 411 km from Addis Ababa, capital of Ethiopia on the way to Bahir Dar. The woreda has limited number of basic infrastructures only one health center in Bure town, four states owned clinics, 22 primary schools, one High School and one Agricultural Technical Collage (Bure Rural Development and Agricaltural Bureau, 2004).

The district has a total number of 28,205 peasant households where male-headed households account for about 88% of total households. Female-headed households constitute the remaining 12% of total households in the district. Total number of households in the selected two kebeles is 3,760 of which 2,139 and 1,621 households are living in Wan Gedam and Wondegi Kebele, respectively. The sample size of 260 households (about 7% of households of the two kebeles) was selected.

These Kebeles are endowed with sufficient water sources. More specifically, Wan Gedam Kebele has Cilala River, which is a tributary of Abbay River. This river is the main supplier of water for irrigation purpose and for domestic uses. The Kebele has 24 small and large springs which are used for different purposes such as irrigation, domestic uses and livestock watering. Wondegi Kebele has three major rivers, namely, Yisir, Muzuz, and Citty Rivers, which are used for irrigation and domestic purposes. This Kebele has also different springs, which are both used for irrigation and domestic activities.

Table 4.1: Summary of Surveyed Households Characteristics

Variable	Description	Mean	Std. Dev.	Min	Max
age	Age of the Respondent (in years)	45.396	13.226	18	82
fsiz	Family size of the Respondent	5.692	1.978	1	11
edu	Educational level of the Respondent	1.461	2.618	0	12
male	Dummy for sex: male=1 if sex=male, 0 otherwise	0.812	0.392	0	1
fem	Dummy for sex: fem=1 if sex=female, 0 otherwise	0.188	0.392	0	1

Source: Summary of sample survey

Family head sex composition of sampled individuals indicates that about 81% are male-headed households. The remaining 19% of the surveyed households are female-headed households (see table 4.1). Almost all household heads interviewed in this study are decision makers both economically and socially and hence the CV survey responses obtained from these individuals are more reliable. The sampled households have a total number of 1480 family sizes with a minimum of one member and a maximum of eleven members averaging at about 5.69 members per household. About 53 percent of sampled households have family members ranging from 4-6 implying that majority of sampled households have family members concentrated around the central value. Only 13.5 and 18.8 percent of the households have family members less than or equal to three and greater than or equal to eight, respectively.

As indicated in table 4.1 above ages composition of sampled households depicts that age ranges from 18 to 82 years with average age of 45.4 years. Categorizing age of respondents witnesses that about 38.8 percent of respondents are 50 years old or above whereas the young class (age less than 35 years) account for nearly 21.3 percent of our sampled households. These imply that surveyed households are dominated by older people. Sex wise, average age of male respondents is 45.4 years (approximately equal to that of total sampled households) ranging from 20 to 82 year. Similarly, average age of female respondents is 45.5 years (again approximately equal to the average age of total sampled households) with a range of 18 to 68 year. This implies that average age is almost the same across sex.

Formal education of respondents varying from zero (illiterate) to grade 12 complete with an average formal school attainment of 1.5 years implying that majority of the sampled households are illiterate or primary school attendant (see table 4.1). About 20 percent of respondents are at least grade four completed.

4.1.2. Income, Expenditure and Wealth of Surveyed Households

Farmers in the study area are engaged in mixed farming activities. These activities include stable food crops production like ‘dagusa’, maize, ‘teff’, wheat, and barley and vegetables and fruits production including tomatoes, potatoes, onions, carrots, peppers, cabbages, beetroot, bananas, coffee, orange, and sugar cane. In mixed farming farmers are also rearing domestic animals such as cows, oxen, sheep and goats, donkeys, mules and beehives.

Major sources of income in the study area are on-farm activities mainly from crops, fruits and vegetables. Farmers also earn income from sales of livestock and livestock by-products (like butter, skins and honey). Income from others sources such as trading crops and livestock, renting ox, mule and land, producing traditional alcoholic drinking and remittance from relatives are also sources of income for some farmers. Income of the surveyed households is ranging from 456.5 to 12,239 Ethiopian Birr with an average value of Birr 4,729.65 per annum (see table 4.2). Taking the average family size of 5.69 average per capita income is Birr 831.22 and 69.27 per annum and per month, respectively. This is higher than Birr 62.7 monthly average per capita income reported by the IMF at country level (IMF, 2001).

On expenditure side, surveyed households spent on food, non-food items (like clothing, education, health and transport), and agricultural related activities including expenditure on fertilizers, selected seeds, chemicals, and renting ox and plot of land. On average household expenditure is Birr 5,077.15 per annual with a range of Birr 1,177 to Birr 12,061.4 per year. Comparing average expenditure with average income of households the former is higher than the latter implying that households tend to underestimate their actual income. As a result, expenditure is used as a proxy for income in our regression analysis as expenditure better indicates households' actual income level.

Finding wealth indicators is very difficult in rural areas of most developing countries. Sometimes corrugated iron roofed houses can be taken as proxy for wealth. But in the study area of this paper over 91 percent of sampled households have corrugated iron roofed house regardless of their wealth. This implies that corrugated iron roofed house could not be good proxy of wealth in our case. Ownership of oxen can also be taken as wealth indicators as oxen are major traction power in rural areas where most households depend on agriculture for their livelihoods. Besides, total number of livestock owned by a household is taken as a proxy of wealth of the household. This wealth indicator seems better as total number of livestock includes and other domestic animals. Thus, total monetary value of all livestock owned by a farmer is used as a proxy for wealth of the respondent.

The surveyed households have a total numbers of 372 oxen, 190 cows, 116 bulls, 125 calves, 417 goats and sheep, 8 mules, 31 donkeys and 93 beehives with the corresponding average of 1.43, 0.73, 0.45, 0.48, 1.60, 0.03, 0.12 and 0.36 (see table 4.2). This implies that, on average, surveyed households have more than one ox but they have less than one cow, bulls and other domestic animals. The surveyed households have a total of 273 hectares of land under cultivation, which includes both owned and rented plot of land with an average size of about one hectare. Cultivated land size of the respondents is ranging from 0 to 3.5 hectares (see table 4.2). Average cultivated land holding per person is about 0.18 hectares for the sampled households (assuming 5.69 persons per household).

Table 4.2: Summary of Households' income, expenditure, wealth and cultivated land holding

Variables/Items	Mean	Std. Dev.	Min	Max	Total
Total income (in Birr per year)	4729.646	2083.76	456.5	12239	1,229,708
Total Expenditure (in Birr per year)	5077.146	1798.958	1177	12061.4	1,320,058
Total land size (in hectares)	1.049	0.475	0	3.5	273
Oxen	1.431	0.962	0	4	372
Cows	0.731	0.949	0	5	190
Bulls	0.4461	0.731	0	4	116
Calves	0.481	0.7881	0	3	125
Sheep/goats	1.604	2.559	0	15	417
Mules	0.031	0.194	0	2	8
Donkeys	0.1191	0.409	0	2	31
Beehives	0.358	1.072	0	6	93
Total value of all livestock	2528.104	1929.256	0	9930	657,307

Source: Summary of sample survey

Total monetary value of all livestock owned by the sampled households is Birr 657,307. On average, monetary value of livestock is Birr 2,528.10 with a range of Birr

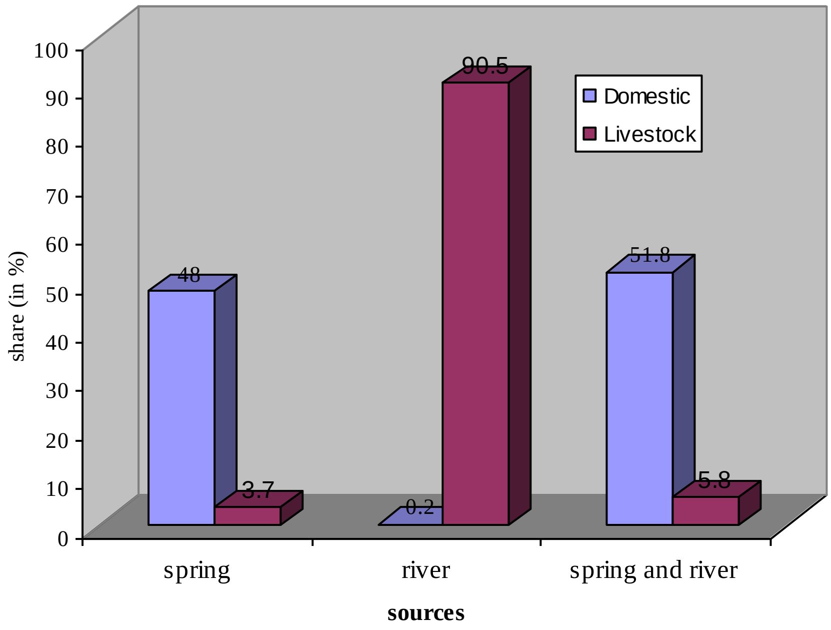
0 to Birr 9,930 implying that some (about 8.5%) of surveyed households have no livestock.

4.1.3. Multiple Uses of Irrigation Water

It is about that irrigation water from river (before and after diversion) and major springs is used for crop production mainly vegetables (cabbage, tomatoes and potatoes) and fruits (orange, banana and coffee). Apart from irrigating crops, irrigation water from both sources is used for domestic purpose (including drinking, cooking, washing and cleaning household equipment), livestock watering and gardening. In rural area of Bure district where piped water supply is limited or non-existing but with relatively abundant irrigation water, most households use irrigation water from both rivers and spring for non-crop purpose such as drinking, cooking, washing and livestock watering.

In two selected kebeles (Wan Gedam and Wondegi) in Bure woreda, large proportion of households consumes water from springs and rivers that provide water for irrigation purposes. As indicated by figure 4.1 about 51.8% of the household uses water from both springs and rivers for domestic uses that are used by farmers for irrigation activities. About 48% collect water from springs only for domestic, which is used for irrigation purposes directly (before flowing to the nearby river) and/or after joining the river. In case of livestock over 90% of sampled household use irrigation water from rivers before and after diversion and from small traditional canal built on rivers.

Fig. 4.1: Share of multiple uses of irrigation water by sources and uses



Moreover, figure 5.2 and 5.3 revealed how irrigation water in the study areas is used for multiple uses.??

Thus, figure 4.1 above witnesses that almost all households in the selected kebeles used irrigation water for non-agricultural uses either from springs, rivers or both. However, in most cases when irrigation water system have been developed, there is tendency to focus exclusively on irrigation water in terms of irrigation water administration (water user association) and traditional water a leaders (water father), irrigation water allocation and irrigation water project designing. This implies that most often multiple uses of irrigation water are ignored in designing irrigation projects, managing and allocating irrigation water. As rural population is growing and irrigation water scarcity is felt among farmers, ignoring multiple uses of irrigation water may lead conflicts among uses and users. On the other hand, providers of improved and potential rural water for domestic uses rarely conceder the uses of irrigation water for such purposes. These imply that in developing and maintaining water and improved rural water supply multiple uses of water from a given source is not considered by responsible bodies.

4.2. Multivariate Analysis of Determinants of Households' WTP

Econometric analysis helps in providing more insight about determinants that affect responses of households to CV survey questions. These determinants are mainly socio-economic variables and property right regimes that govern allocation of irrigation water among uses. In modeling determinants of non-crop uses of irrigation water we employ a step-wise deletion of variables based on different criteria (like coefficient of determination) to identify explanatory variables that better explain the dependent variable (the binary response to the initial bid).

4.2.1. The Probit Model Estimation Results

Estimation results of the probit model are reported based on theoretical model that has already been developed in the preceding chapter. Such statistical relationship is used to examine whether WTP responses of surveyed households are systematically related to socio-economic and other relevant variables or not. The probit model estimation results are presented on determinants of households' WTP for domestic use of irrigation water without proposing changes in the quality of the existing water supply from irrigation systems for domestic uses and after some improvements are proposed concerning quality of irrigation water. The summary results of conventional probit model estimates are reported in table 4.3 below.

Table 4.3: the probit model estimation results of households' WTP

Estimation Results of the probit model- without improvement				Estimation Results of the probit model- with improvement		
Dependent variable is discrete response (yes=1/no=0) to initial bid (β^*)				Dependent variable is discrete response (yes=1/no=0) to initial bid (β^*)		
Explanatory variables	**Coef.**	**Std. Err.**	**Z-Value**	**Coef.**	**Std. Err.**	**Z-Value**
constant	1.5814	0.4086	3.87***	1.0408	0.5112	2.05**
ibidy	-0.0298	0.0063	-4.70***	-0.0161	0.0035	-4.65***
lexp	1.4286	0.4573	3.12***	0.8731	0.4882	1.79*
val	—	—	—	0.0001	0.0001	1.00
dis	0.0011	0.0008	1.47	0.0001	0.0007	0.14
age	0.1537	0.0695	2.21**	0.0390	0.0614	0.64
fsiz	-0.1675	0.088	-1.89*	-0.1267	0.0683	-1.86*
fem	0.2956	0.3426	0.86	0.1277	0.3159	0.40
s1	0.8190	0.3569	2.29**	0.7250	0.3335	2.17**
edu1	0.6933	0.3375	2.05**	0.4702	0.2858	1.65*
loc2	0.1850	0.3606	0.51	0.1504	0.3329	0.45
loc3	-1.0582	0.3887	-2.72***	0.6743	0.3573	1.89*
sour2	1.5815	0.5126	3.09***	0.5318	0.4489	1.18
agesq	-0.0014	0.0007	-2.00**	-0.0002	0.0006	-0.33
qaun	0.3541	0.1479	2.39**	0.4084	0.1416	2.88***
ten2	1.0858	0.3519	3.09***	0.7262	0.2880	2.52**
ten3	0.4132	0.4951	0.83	-0.4008	0.4674	-0.86
adm3	-2.0440	0.7873	-2.60**	-0.8705	0.7318	-1.19
adm4	-3.1215	0.8991	-3.47***	-2.8386	0.7880	-3.60***
chr3	-3.1093	0.7666	-4.06***	-2.5500	0.6913	-3.69***
chr5	-0.8995	0.3241	-2.78***	-0.1998	0.2863	-0.70
qaul2	-0.5631	0.3101	-1.82*	0.0861	0.3876	0.22
qaul3	-0.6869	0.4151	-1.65*	0.6198	0.3489	1.78*
use2	0.9816	0.4674	2.10**	0.7682	0.4010	1.92*
Number of obs = 260 LR chi2(22) (χ^2) = 209.32 Prob > chi2 (χ^2) = 0.0000 Log likelihood = -73.585 Pseudo R^2 = 0.5872				Number of obs = 260 LR chi2(23)(χ^2) = 176.51 Prob > chi2 (χ^2) = 0.0000 Log likelihood = -90.454 Pseudo R^2 = 0.4938		

***, ** & * indicate significant level at 1%, 5% and 10%, respectively.

As depicted in table 4.3 the measure of over all significance of the model, namely, livelihood ratio (LR), which assumes the chi-square (χ^2) distribution, is 209.32 for the probit model with 22 degree of freedom (df) to estimate WTP for domestic uses of irrigation water without proposing any change and it is 176.51 for the fitted probit model with 23 df after change in quality of irrigation water for domestic use is proposed. The critical value of chi-square statistic from the chi-square table is 8.64 and 9.26 for the former and the later model with 22 and 23 df at 99.5% level of significant. This implies that the joint null hypothesis of coefficients of all explanatory variables included in the models are zero is rejected. Thus, the over all significance of the model is good (i.e. the model better fits the data).

Other measure of goodness of fit of the model is McFadden's pseudo R^2, which is equivalent to coefficient of determination (R^2) in conventional regression model. Pseudo R^2 is 0.587 and 0.494 for the probit model employed to estimate probability of accepting the initial bid for domestic use of irrigation water without any change and after an improvement is introduced, respectively (see table 4.3). This replies that the model explains about 59% and 49% of the variation in explained variable for the respective probit models (i.e., the goodness of fit of the model is adequate).

As indicated under the column of the probit estimate of existing water supply of table 4.3 significance and signs of most explanatory variables are as expected except distance from existing water sources which is positive but statistically insignificant at permissible error and total value of livestock to proxy wealth of respondents which is omitted from this model due to its wrong sign. It is unusual to have statistically insignificant impact of sex (female=1) on the likelihood of WTP for domestic uses of irrigation water as females are responsible to fetch water from irrigation systems. Among important explanatory variables income, age, education dummy (edu_1 =1 if education level is greater than or equal to 4), quantity of water consumed and dummy for land size reduction due to population growth has positive effects on the probably of households' WIP for domestic uses of irrigation water.

Other crucial explanatory variables, which have negative impact on respondents' WIP for domestic uses of irrigation water are the initial bid, quality of irrigation water (good quality is base group), irrigation water management under water farmer (WF) and community based management (i.e. open access) by taking management by water users associations (WUAs) as reference group and choices of irrigation water rights under WF and open access (considering WUAs as base group).

In the case of probit model for improved rural water supply distance from the proposed improved water supply has wrong sign but statistically insignificant. Other variable such as total value of livestock (proxy for wealth), age and sex of respondents have expected signs but statistically insignificant. Income of respondent, education, quality of water consumed and reduction of land size (that leads to intensive land farming practices) are among independent variables that have positive effects on probably of respondents accepting the posted bid. Family size, irrigation water management falling under the umbrella of WF and open access and choices of water use rights under WF and open access are negatively related to likelihood of saying yes to the first bid.

It is clear, however, that the coefficients of the probit model do not indicate the marginal effects of explanatory (right hand side) variables on the dependent (left hand side) variable. That is, in the probit model only the signs (not the magnitudes) of the coefficients of independent variables are important. In order to analyze the effects of each explanatory variable on the probability that respondents accept or reject the initial bid (β^*), the partial derivatives of explanatory variables with respect to discrete responses must be taken (Greene, 1993). The marginal effects of the probit model estimation results are reported in the table below.

Table 4.4: Marginal Effect Estimates of the probit model

Estimation Results of the probit model- without improvement					Estimation Results of the probit model- with improvement			
Dependent variable is discrete response (yes=1/no=0) to initial bid (β^*)					Dependent variable is discrete response (yes=1/no=0) to initial bid (β^*)			
Variables	**dF/dx**	**Std. Err.**	**Z-Value**	**x-bar**	**dF/dx**	**Std. Err.**	**Z-Value**	**x-bar**
ibidy/ibidiy	-0.0109	0.0022	-4.70***	44.077	-0.0062	0 .0013	-4.65***	66.115
lexp	0.5229	0.1668	3.12***	8.466	0.3375	0.1893	1.79*	8.466
val	—	—	—		0.00004	0.00003	1.48	2528.10
dis	0.0004	0.0003	1.47	223.904	0.00004	0.0002	0.18	223.904
age	0.0563	0.0254	2.21**	45.396	0.01509	0.0237	0.64	45.396
fsiz	-0.0613	0.0327	-1.89*	5.692	-0.0490	0.0263	-1.86*	5.692
fem†	0.1116	0.1318	0.86	0.188	0.0498	0.1239	0.40	0.188
s1†	0.2889	0.1179	2.29**	0.542	0.2724	0.1199	2.17**	0.542
edu1†	0.2614	0.1266	2.05**	0.501	0.1836	0.1111	1.65*	0.501
loc2†	0.0694	0.1378	0.51	0.146	0.0572	0.1245	0.45	0.146
loc3†	-0.3019	0.0802	-2.72***	0.138	0.2347	0.1075	1.89*	0.138
sour2†	0.5269	0.1379	3.09***	0.519	0.2028	0.1669	1.18	0.519
agesq	-0.0006	0.0003	-2.00**	2235.07	-0.0001	0.0002	-0.33	2235.07
qaun	0.1296	0.0542	2.39**	3.017	0.1579	0.0548	2.88***	3.017
ten2†	0.3661	0.1023	3.09***	0.592	0.2700	0.1003	2.52***	0.592
ten3†	0.1584	0.1944	0.83	0.119	-0.1465	0.1583	-0.86	0.119
adm3†	-0.6848	0.1934	-2.60***	0.612	-0.3329	0.2669	-1.19	0.612
adm4†	-0.4537	0.0624	-3.47***	0.096	-0.5062	0.0560	-3.60***	0.096
chr3†	-0.6341	0.0873	-4.06***	0.246	-0.6318	0.0878	-3.69***	0.246
chr5†	-0.3116	0.1048	-2.78***	0.427	-0.0768	0.1092	-0.70	0.427
qaul2†	-0.2065	0.1122	-1.82*	0.558	0.0335	0.1520	0.22	0.558
qaul3†	-0.2106	0.1082	-1.95*	0.092	0.2425	0.1341	1.78*	0.092
use2†	0.3744	0.1702	2.10**	0.188	0.2991	0.1490	1.92*	0.188
Number of obs = 260 LR chi2(22) (χ^2) = 209.32 Prob > chi2 (χ^2) = 0.0000 Log likelihood = -73.585 Pseudo R2 = 0.5872					Number of obs = 260 LR chi2(23) (χ^2) = 176.51 Prob > chi2 (χ^2) = 0.0000 Log likelihood = -90.454 Pseudo R2 = 0.4938			

***, ** & * indicate significant level at 1%, 5% and 10%, respectively.

† dF/dx is for discrete change of dummy variable from 0 to 1

The interpretation of the marginal effects of the probit model indicates the change in the probability (or likelihood occurrence) of an event due to a unit change in the continuous explanatory variables and the change of dummy variables from 0 to 1 for discrete variables.

Table 4.4 indicates that, holding other things constant, a one Birr increase in income of the respondent will pick-up the probability of accepting the first bid by about

0.52% and 0.34%, respectively, proposed for domestic uses of irrigation water before and after improvements are introduced. This witnesses that a household with higher income is willing to pay more for domestic uses of irrigation water.

Since supporting other family members is the responsibility of head of the household, respondents with larger family size are less likely to pay for non-agricultural uses of irrigation water. As it can be seen from table 5.4, an increase in family size reduces probability of saying yes to the posed prices by 6% and 5% for existing and improved irrigation water for domestic uses, respectively.

Age of the respondents increases the likelihood that users of irrigation water for domestic uses are willing to pay for such uses if they are required but it is statistically insignificant for improved irrigation water supply. The possible explanation for the significant effects of age on the WTP for existing irrigation water is that age could be taken as experiences and hence individuals with higher ages better know about the benefits of irrigation water. However, as the coefficient of age-squared is negative (about -0.001 or -0.1%) there is a maximum age beyond which probability of paying for domestic uses of irrigation water falls.

Holding other things constant, change in education level of the respondent from less than grade four to greater than or equal to grade four increases the probability that respondents are willing to pay the proposed bid by about 26% and 18% for domestic uses of irrigation water for existing and improved irrigation water. One possible reason could be that more literate individuals are concerned about environmental goods including irrigation water. The coefficient of loc3 (dummy variable for end or lower users of irrigation water) is negative (-0.3) and it is statistical significant at 1% permissible error. This implies that end users are less likely to pay for domestic uses of irrigation water compared to the upper users (our reference groups). Because quality of irrigation water gets poorer as it moves down the canals. The negative impact of low quality of irrigation water on the probability of paying for it for domestic uses is also revealed by the coefficients of qual3 (dummy for bad quality) and qual2 (dummy for satisfactory quality) against the reference groups(irrigation water with good quality) (see table 4.4).

Households anticipating reduction in farm plot due to higher family members are willing to pay more compared to the reference group (those anticipating no change). That is, keeping other things constant, changing the dummy from 0 to 1 (i.e., from base group to those anticipating land size reduction due more family size) will increase probability of accepting the initial bid by about 37%. This is probably due to the fact that smaller and smaller farm plot enforces farmers to practice intensive farming activities that require more irrigation water and irrigation water becomes a scarce resource. The scarcity of irrigation water induces farmers to pay more for multiple uses of this resource.

Irrigation water managements and administrations to ensure equity (i.e., minimize conflicts over irrigation water among users) and improve efficiency (avoid irrigation water misallocations) are crucial explanatory variables in our model. Respondents use irrigation water managed by water father (WF) and the community itself are less willing to pay for multiple uses of irrigation water compared to those using it under WUAs (the reference group) (see table 4.4). The reasons may include: firstly, individuals organized under the umbrella of WUAs have more awareness about benefits of irrigation water but those under WF and community based management systems may not have such awareness. Secondly, the problems of "free riders" are expected to be high in the case of WF and community based irrigation water management as they do not have strong legal bases and rights enforcing mechanisms. Lastly, WUAs provide various services such as fertilizers, selected seeds and marketing for their members, which could play important role in increasing income of their members. The same explanation could be given for choices of irrigation water use rights in which respondents chose WF and community based irrigation water use rights are willing to pay lower against the reference group (WUAs) (see table 4.4).

The important policy implication here is that organizing irrigation water users under WUAs facilitates efficiency and equity in allocating irrigation water among uses and users. Households choosing WUAs are willing to pay more for multiple uses of irrigation water. This implies that it is possible to introduce irrigation water user fees that can signal scarcity of irrigation water.

For both models initial bids have negative effects on the probability of accepting that bid implying that an increase in the initial bid reduces the likelihood that respondents are paying the posed bid, which is logical (see table 4.4).

5.2.2. Bivariate Probit Model Estimation Results

Unlike the conventional probit model (or single-bounded probit model), the bivariate probit model (or the double-bounded probit model) of this study is estimated using responses to the first and the second bids. Other explanatory variables such as socio-economic variables and irrigation water rights that govern irrigation water allocations are omitted from double-bounded model as most of them are statistically insignificant in the second equation. The probit estimates of the double-bounded CV responses are summarized in table below.

Table 4.5: The bivariate probit model estimates for domestic uses of irrigation water

The bivariate estimates for domestic uses of irrigation water (without improvement)

Variables	Coef.	Std. Err.	Z-Value
Dependent variable (yesno=1 if yes to the initial bid), 0 otherwise			
Initial bid per year	0.0191	0.0038	-5.08
Constant	0.8707	0.1856	4.69
Dependent variable (yes2=1 if always yes to the second bid), 0 otherwise			
Second bid per year	-0.0138	0.0072	-1.91
Constant	0.3559	0.2969	1.20
Rho (**ρ**)	0.6507	0.0821	
Number of obs = 260 Wald chi2(2)(χ^2) = 26.93 Prob > chi2 (χ^2) = 0.0000 Log likelihood = -322.78805			

Likelihood ratio test of rho=0: chi2(1) = 38.3045 Prob > chi2(χ^2) = 0.0000

The bivariate estimates for domestic uses of irrigation water (After proposing improvements)

Variables	Coef.	Std. Err.	Z-Value
Dependent variable (yesno=1 if always yes to the initial bid), 0 otherwise			
Initial bid per year	-0.0105	0.0023	-4.52
Constant	0.6110	0.1685	3.63
Dependent variable (yes2=1 if yes to the second bid), 0 otherwise			
Second bid	-0.0163	0.00471	-3.46
Constant	0.6571	0.1718	3.83
Rho (**ρ**)	0.7734	0.0670	
Number of obs = 260 Wald chi2(2)(χ^2) = 22.04 Prob > chi2 (χ^2) = 0.0000 Log likelihood = -317.06772			

Likelihood ratio test of rho=0: chi2(1) = 60.1422 Prob > chi2(χ^2) = 0.0000

In the double-bounded estimates reported above the initial bid and the second bid have the expected signs and statistically significant at usual level of significance implying that higher initial bid and second bid lead to lower probability of accepting that bid.

In our fitted bivariate model Rho (ρ), coefficient of correlation of error terms of the double-bounded model, is positive and statistically significant at 1% level of significance. This basically shows that there is positive linear relationship between the random components of the responses to the initial bid and the second bid. The fact that Rho (ρ) is less than unity indicates that the correlation between the random components of the responses to the initial bid and the second bid is not perfect.

5.2.3. Single-Bounded and Double-Bounded Models Estimates: A Comparison

In order to compare the statistical efficiency of double-bounded and single-bounded dichotomous CV questions, two models were fitted using the CV survey data of this study collected from the Blue Nile River basin of the Amhara regional state of Ethiopia. The conventional single-bounded model was fitted using responses to the initial bids while the double-bounded model was estimated using responses to both the first and the second bids. The estimation results of both models are reported in table5.6 below.

Table 4.6: Probit and Bivariate probit Estimates for Households' WTP

Descriptions	**Single-Bounded Model**			**Double-Bounded Model**		
Irrigation water (without proposing improvements)	**Coef.**	**Std. Err.**	**Z-Value**	**Coef.**	**Std. Err.**	**Z-Value**
Initial bid (per year)	-0.0206	0.0039	-5.28	-0.0191	0.0038	-5.08
Constant	0.9480	0.1920	4.94	0.8707	0.1856	4.69
Irrigation water (after proposing improvements)	**Coef.**	**Std. Err.**	**Z-Value**	**Coef.**	**Std. Err.**	**Z-Value**
Initial bid (per year)	-0.0113	0.0024	-4.76	-0.0105	0.0023	-4.69
Constant	0.6659	0.1751	3.80	0.6110	0.1685	3.63

Statistical efficiency of double-bounded model versus single-bounded model can be compared from three perspectives. First, the precision of the estimates of the intercept term and coefficient of bids, which is measured using estimated standard errors. Second, the goodness of fit of the estimated models using pseudo R^2 . Lastly, the precision of the estimates of welfare measures derived from the underlying coefficients of bids (Hanemann, Loomis and Kanninen, 1991).

In our case, standard errors of the coefficients of bids and constant terms are approximately the same for both double-bounded and single-bounded models, which lead to the same t-statistics (see table 4.6). Pseudo R^2 , which is the measures of goodness of fit, does not deviate much from each other. These facts imply that in the limited number of observation (or sample size) efficiency gain from using double-bounded model over single-bounded model is not significant as such. Therefore, we use only estimates of single-bounded model to calculate central values of households' WTP for domestic uses of irrigation water.

5.3. Summary of Households' WTP and Estimation of Total WTP

5.3.1. Summary of Households' Responses to Discrete Choice Questions

Table 4.7 reports average values of the initial bid, the second bid and numbers of yes responses to the first and second bids.

Table 4.7: Descriptive Statistics of Households' Responses to Double-Bounded Questions

Variables	**Current Status**		**Improved Water**	
	Mean	Std. Err.	Mean	Std. Err.
Initial (first) bid	44.0792	21.5678	66.1153	34.4385
Second bid	44.0692	21.5274	65.5769	33.9892
Discrete Responses for the first bid	0.5115	0.5000	0.4700	0.5000
Discrete Responses for the second bid	0.5269	0.5002	0.5461	0.4988

Source: Summary of sample survey

The average initial bid is Birr 44.08 and 66.12 for irrigation water at existing status and after some improvements are proposed, respectively. The second bid for the respective quality of irrigation water is Birr 44.08 and 65.58. The yes response for the first bid is about 51% for irrigation water without improvements and 47% after the improvements are introduced. The basic explanation for low yes responses after the proposed improvements is due to higher initial price (about Birr 66) compared to Birr 44 for existing irrigation water for domestic uses (see table 4.7).

5.3.2. Average Values of Maximum WTP: Open-ended Question Responses

Respondents' maximum WTP to the open-ended elicitation format for various uses of irrigation water is summarized as follows:

Table 4.8: Annual Average WTP across Uses of Irrigation water: Open-ended Questions Results

Types of Uses	Mean	Std. Err.	Min.	Max.
Domestic uses (without improvements)	35.8039	30.0575	0	180
Domestic uses (after improvements)	54.2808	42.7861	0	190
Livestock watering	38.6654	52.6263	0	280
Gardening	41.7885	37.2785	0	200

Source: Summary of sample survey

Generally, respondents are willing to pay for multiple uses of irrigation water. The average WTP results obtained from the open-ended questions vary from about Birr 35.8 for domestic uses (at existing status) to Birr 54.28 for improved water for domestic uses per annum. The minimum willingness to pay is Birr zero mainly referring to protest zeros (in all cases of uses of irrigation water) with maximum WTP of Birr 280.00 for livestock consumption.

Although invalid zero exists in all cases, it is the lowest for improved irrigation water supply for domestic uses (about 0.8%) followed by zeros in paying for gardening (about 3.8%). One possible explanation for low protest zeros in the case of gardening is that farmers are paying irrigation water to uses for agricultural especially during dry seasons in the informal markets implying that farmers have already been exercising purchasing irrigation water. The policy implication is formalizing such markets could lead to efficient allocation of irrigation water.

5.3.3. Calculating Mean WTP: Single-Bounded Model Estimates Results

One of the main objectives of estimating an empirical WTP model based on the CV survey responses is to derive a central value (or mean) of the WTP distribution (Hanemann, Loomis and Kanninen, 1991). The mean WTP (μ) is defined as follows:

$$\mu = -\frac{\alpha}{\beta}$$

Where: $\alpha =$ the constant (or intercept) term

$\beta =$ the coefficient of the bid posed to the respondent

Then mean WTP (μ) can be computed using this formula and the coefficient of single-bounded model given in table 5.6. Thus mean WTP is Birr 45.6 & 58.2 for domestic uses of irrigation water without proposing changes and after improvements are introduced, respectively. The respective mean WTP is Birr 35.8 & 54.3 from responses to open-ended CV survey questions, which are lower compared to the mean values obtained from the single-bounded probit model estimates. Based on the double-bounded model estimates the mean WTP varies from Birr 25.8 to 45.55 for domestic uses of irrigation water without proposing changes and Birr 40.35 to 58.1 after improvements are introduced. Still even the upper bounds of the mean values from the double- bounded model estimates are slightly lower than that of single-bounded model.

5.3.4. Estimating Total WTP

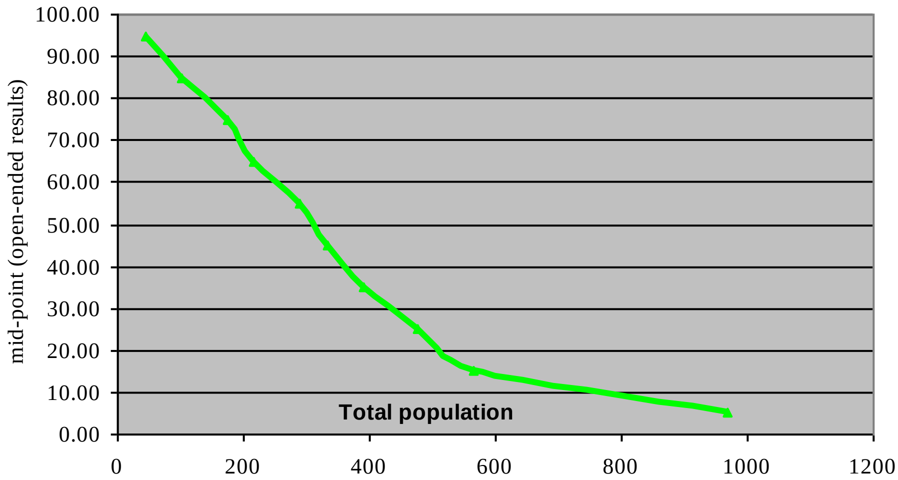
Total WTP for the total households in the selected kebeles can be computed using the average WTP from open-ended responses, single-bounded and double-bounded models (see table 4.9).

Table 4.9: Total WTP for Domestic uses of irrigation water (in birr per year)

Items	Total Households	Single-bounded	Total	Open-ended	total	Double-bounded	total
	Existing Irrigation Water						
Wan Gedam	2,139	45.6	97,538.4	35.8	76,576.2	25.8	55,186.2
Wondegi	1,621	45.6	73,917.6	35.8	58,031.8	25.8	41,821.8
Total	**3,760**		**171,456**		**134,608**		**97,008**
	Improved Irrigation Water						
Wan Gedam	2,139	58.2	124,489.8	54.3	116,147.7	40.35	86,308.65
Wondegi	1,621	58.2	93,342.2	54.3	88,020.3	40.35	65,407.35
Total	**3,760**		**217,832**		**204,168**		**151,716**

4.3.5. Aggregate Demand for Domestic uses of irrigation water

Fig 4.2: Aggregate demand of irrigation water (current quality)



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