Effects of Information Framing on Smallholder Irrigation Farmers' Willingness to Pay for Groundwater Protection: The Case of Vea Irrigation Scheme in Ghana[1]

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Abstract

In Ghana, groundwater, accessed through wells and boreholes, is widely used by rural households due to limited sources of potable water. These wells and boreholes are generally unregulated and in some cases, may be contaminated with pollutants including excess nitrates from agricultural chemical fertilizers, manure, or sewage. Yet, studies estimating the economic value of groundwater in Ghana are not available. To evaluate how information affects farmers' valuation of groundwater protection in a developing country setting, this paper estimates smallholder irrigation farmers' preferences for groundwater protection under the Vea irrigation scheme in Ghana using two contingent valuation scenarios: environment and health. We used the double-bounded contingent valuation approach to estimate farmers' willingness to pay (WTP) for inputs that protect groundwater quality. The mean willingness to pay from the entire sample is GHC 69, or about US$ 17 per acre. The mean WTP from the health scenario subsample is about GHC 79 or US$ 20 per acre, while that from the environmental scenario subsample is about GHC 57 or US$ 14 per acre. Our results show that farmers who receive the health scenario are willing to pay more than those who received the environmental scenario. We find that the primary water source significantly impacts the WTP to protect groundwater. Other factors that impact willingness to pay are gender, level of education, quantity of chemical fertilizer used, and income from farming under the Vea Irrigation scheme.

1. Introduction

Agricultural production frequently generates externalities that negatively affect human and environmental health (Johnson et al., 1987; Spalding and Exner, 1993; Ward et al., 2005). For instance, manure or chemical fertilizers used in agricultural production may leach into groundwater and lead to illnesses from consumption of contaminated groundwater. Though water quality is an issue throughout the world, developing countries in particular struggle to invest in the education, infrastructure, or oversight needed to monitor and address water quality issues. In many cases, the success of groundwater quality management policies hinges on farmers' voluntary compliance with leaching reduction measures, such as their willingness to adopt production practices that are more expensive but reduce leaching of chemicals (Lichtenberg and Zimmerman, 1999).

A measure of individuals' valuation of water quality, one justification for costly investments in infrastructure to guarantee access to clean water, is rarely available in developing countries. A significant literature on methods to elicit water quality valuation, which has predominantly been applied to populations in developed countries, has developed over the last few decades (National Research Council, 1997). Additionally, research in behavioral economics and other decision sciences suggests that directing respondents' attention to different consequences of decreased water quality will likely result in divergent measures of value. In a recent study, for instance, Asensio and Delmas (2015) demonstrate that households decrease energy consumption significantly more when informed of the health consequences of energy-related emissions than for households told about how much money they could save by reducing energy use. To examine the effects of information framing on producers' willingness to pay (WTP) for groundwater quality in a developing country setting, we address the following questions: first, are farmers willing to pay to protect groundwater quality? Second, does farmer WTP differ if effects are framed in terms of human health or environmental health?

A survey of the nonmarket valuation literature suggests that groundwater values can be estimated using either indirect (observed behavior) or direct (survey based) approach (National Research Council, 1997). Averting behavior, the most common indirect approach used in valuing services related to groundwater quality (National Research Council, 1997), has been used in estimating averting expenditures of households in response to prevalence of groundwater pollution (Smith and Desvouges, 1986; Abdalla, Roach, and Epp, 1992). The averting behavior approach provides a lower bound of WTP, and is relatively inexpensive to implement, but fails to estimate nonuse values (National Research Council, 1997). The contingent valuation method (CVM) is the main direct approach to measuring economic values. It is a survey-based approach used to measure the values individuals place on goods or services (Boyle, 2003). It can measure all components of economic value (National Research Council, 1997), and has been used in various groundwater valuation studies (e.g., Edwards, 1988; Shultz and Linsay, 1990; Jordan and Elnagbeeb, 1993; Lichtenberg and Zimmerman, 1999).

The CVM has been used extensively to measure groundwater quality valuation in the United States. Lichtenberg and Zimmerman (1999) use the contingent valuation method to estimate corn and soybean growers' willingness to protect groundwater in Maryland, New York, and Pennsylvania. Their approach focuses on pesticide use and farming practices that impact leaching of pesticides. They employ the dichotomous choice approach, which asks respondents only one question whether they are willing to pay certain monetary amounts for the resource or service. They find that farmers are willing to pay more for leaching prevention than nonfarm groundwater consumers, with the primary motivation being concern for environmental quality rather than drinking water quality protection or health and safety of respondents and their families. Jordan and Elnagheeb (1993) investigate Georgia residents' perceptions of groundwater contamination in addition to estimating their WTP for improved groundwater quality. They use the payment card elicitation format with water bill and water purification equipment as the payment vehicles. Owners of wells and those who received water from public sources were asked whether they were willing to pay certain dollar amounts above their current water bills to help clean nitrates from groundwater. They find that women and younger residents have higher WTP than other respondents. Edwards (1988) estimates households' WTP to prevent nitrate contamination of an aquifer in Cape Cod, Massachusetts using a dichotomous choice CVM. His results reveal that bequest motives have a strong influence on household's WTP. Also, Shultz and Linsay (1990) estimate WTP for groundwater protection in Dover, New Hampshire. Using the dichotomous choice CVM format, they select property taxes as their payment vehicle and ask residents of Dover whether they would be willing to pay extra money in property taxes annually to support groundwater protection. They find that age negatively impacts WTP, and the mean and the median WTP were estimated to be $129 and $40 per year, respectively.

In Europe, Stenger and Willinger (1998) used CVM to study groundwater quality protection and compared WTP of households in polluted areas with those in areas of preserved water quality. They used two versions of a questionnaire that differed by the reliability of the proposed preservation program. They find that reliability of proposed preservation program does not matter and households living in polluted areas have higher WTP compared to others.

A handful of studies have examined the impact of information on WTP for environmental amenities. Bergstrom, Stoll and Randall (1990) develop a conceptual model to study the effects of information about possible uses of a commodity on the magnitude of WTP for environmental commodities. Respondents received information on beneficial consumption services or attributes supported by wetlands. The authors conclude that service information increases WTP for wetland protection. In a CVM study to estimate WTP for environmental amenity benefits of an agricultural land, Bergstrom, Dillman and Stoll (1985) find that informational content of the contingent valuation scenario does influence valuation responses and reaffirm that quality and quantity of information provided to respondents in a CVM study may affect accuracy of responses. Samples, Dixon and Gowen (1986) find that WTP to preserve a species of animal depends on the information provided about the animal's physical and behavioral characteristics, as well as how endangered the population is. Boyle (1989) examines how information presented to respondents about a good affects WTP estimates and concludes that gross changes in a commodity description may markedly alter value estimates, but WTP estimates do not change due to small refinements in a specific commodity description.

To address our research questions, we measure farmers' WTP to protect groundwater quality and investigate further how information about the effects of groundwater quality degradation influence farmers' WTP to protect groundwater quality. Specifically, we examine whether WTP differs when information is provided about effects on human health versus when information is provided about effects on environmental health. We estimate smallholder irrigation farmers' preferences for groundwater protection under the Vea Irrigation Scheme in the Upper East Region (UER) of Ghana using the double-bounded contingent valuation method (DBCVM). The DBCVM consists of two dichotomous choice questions for each respondent. Participants responded to valuation questions under one of two scenarios: a scenario emphasizing the human health effects of water quality, or a scenario emphasizing the environmental effects of water quality. The main objectives of this paper are to investigate how the informational content of a contingent valuation scenario affects farmers' WTP for groundwater protection, and to derive farmer valuation for groundwater quality from the premiums they are willing to pay for fertilizers that provide equivalent levels of nutrients to crops, but which leach into groundwater at a much lower rate compared to the fertilizers commonly used in the area.

This paper advances the literature on impacts of information framing on the valuation of water quality (see Munro and Hanley, 2001), using environment and health-based messaging in a CVM framework. Thaler and Sunstein (2008) suggest that environment and health-based nudges, such as the disclosure of environment and health-based externalities to consumers, can reduce their energy consumption, and hence promote environmental protection. In a randomized controlled experiment, Asensio and Delmas (2015) find that disclosure of environmental and public health externalities of electricity production outperforms monetary savings information in motivating residential behavioral change. The amount of information disclosed to the respondent can influence the outcome of valuation studies (Samples et al., 1986), because values attached to goods depend on the information about these goods available to individuals (Munro and Hanley, 2001). However, the body of literature that has investigated the impact of information on WTP has found mixed results, and further studies on impacts of information on WTP are needed.

This research differs from other groundwater studies based on the different information frames used in the elicitation of WTP: environment and health-based messaging. Also, available CVM studies on water quality in developing countries have only focused on surface water demand or provision of improved water sources (Mu et al., 1990; Whittington et al., 1990; Kremer et al., 2009). This study focuses on valuation of groundwater quality, which is an important source of water for many throughout the world. There are currently no studies to our knowledge that examine groundwater quality valuation in Ghana, and they are also not easily available for other countries in Africa. Our findings will help provide guidance to CVM practitioners and policymakers in the continent who have interests in determining the type of information that may yield higher groundwater values.

2. Background of the Study

There is no comprehensive water policy that governs all aspects of water resource management in Ghana (Government of Ghana, 2007). Under the integrated water resources management (IWRM) approach, both surface and groundwater management in the country is a collective responsibility of the state, local governments, non-governmental organizations, and other stakeholders. The Ghana Ministry of Water Resources, Works and Housing (MWRWH) through the Water Resources Commission (WRC) of Ghana is responsible for the formulation and regulation of water policies in the country. The WRC's long-term vision on groundwater is to formulate groundwater policies that enhance economic activities associated with groundwater use while ensuring the safety of groundwater users and promoting groundwater sustainability, which it strives to achieve within the period of 2011 to 2020 through collection, analysis, and interpretation of groundwater data (Water Resources Commission, 2011).

In Ghana, groundwater is accessed through wells and boreholes and it is widely used by residents of rural areas for domestic purposes because access to potable surface and pipe-borne water in these areas is usually low. The groundwater in some of these rural areas may contain pollutants including excess nitrates from manure or chemical fertilizer applied by farmers (Duah, 2006; Rossiter et al., 2010) because wells and boreholes in the country are unmonitored (Rossiter et al., 2010) and generally unregulated (Kubreziga, 2012).

Groundwater pollution is a public health concern in the Upper East Region (UER), which is where this study was conducted. The 2003 Early Warning and Assessment Report of the United Nations Environment Programme identifies Bolgatanga, the capital city of the UER of Ghana, as a groundwater dependent city (Morris et al., 2003). Morris et al. (2003) define groundwater dependent cities as those whose water supply (domestic and industrial) cannot function without water provided by local urban or peri-urban aquifer systems. At the end of 1980, over 2000 boreholes were drilled in the UER for domestic water supply, and between 1977 and 1980, levels of nitrates in groundwater in the region increased significantly due to increases in chemical fertilizer use in agriculture and changes in animal husbandry practices (Duah, 2006). Even though the application rate of chemical fertilizers in Ghana is considered to be low compared to other Sub-Saharan African countries and the rest of the world, the Upper Regions (Upper East and Upper West) constituted the regions with highest fertilizer use in Ghana from 1997 to 2001 due to the existence of two large irrigation schemes in the UER (FAO, 2005), though with the recent adoption of cocoa fertilizers in the country (Vigneri and Santos, 2008), this may no longer be true.

One of the objectives of agricultural chemical fertilizer policy in Ghana is to promote the efficient use of fertilizers in order to ensure environmental sustainability (MoFA, 2013). This policy objective is achieved through the development and enforcement of legal and regulatory frameworks that are designed to help prevent fertilizer manufacturers and farmers from polluting the environment. Fertilizer regulation in Ghana is governed under the Plant and Fertilizer Act, 2010 (ACT 803) enacted by Parliament (Tarus et al., 2015). The Ghana Ministry of Food and Agriculture (MoFA), through its various directorates, is responsible for formulation, implementation, and regulation of fertilizer policies in Ghana. However, there is evidence that fertilizer regulation in Ghana is ineffective (Enti-Brown et al., 2012), which may stem from resource limitations facing MoFA, including insufficient personnel and costly monitoring (Tarus et al., 2015).

Water quality testing in Ghana has shown degradation of the quality of both surface and groundwater due to excess nitrates. From a nationwide sample of 230 boreholes and wells and other improved drinking water sources in Ghana, Rossiter et al. (2010) report that 21% of the water sources had excess levels of nitrates. A recent study on nitrate concentration of groundwater in the study area finds that three out of every seven unregulated water sources (wells and boreholes) in the region expose consumers to high nitrate-nitrogen concentrations that exceed the World Health Organization's (WHO) acceptable level of 10 mg/L (Kubreziga, 2012). Water quality studies in other parts of the country find similar results. Boadu and Owusu-Nimo (2011) find that over a period of 12 months, nitrate-nitrogen concentration levels in wells across the Nsawam district ranged from 0.1mg/L to 39.1 mg/L. They attribute these excess levels of nitrates in groundwater to heavy use of nitrate fertilizers by farmers in the district. Fianko et al. (2009) also find that about half of 18 boreholes sampled in the Eastern region had levels of nitrates beyond WHO's recommended level for drinking, which they also attribute to sewage and the use of chemical fertilizers.

The presence of nitrates in drinking water has been linked to a number of serious health problems. Ingestion of excess nitrates is the main cause of a fatal condition known as methemoglobinemia or blue-baby syndrome in infants below six months of age (Johnson et al., 1987). Johnson et al. (1987) reveal that methemoglobinemia contributed to infant mortality in the US. They highlight the death of infant of a farm family in South Dakota due to supplementary feedings mixed with well water. Kubreziga (2012) reports that one out of every 12 children in the UER faces risk of methemoglobinemia due to use of water from unregulated sources. Some studies also argue that excessive nitrate-nitrogen levels cause stomach or gastrointestinal cancer (Gulis et al. 2002; Sandor et al. 2001).

Increasing access to clean water and sanitation is key to reducing child mortality (UNDP, 2006). Infant mortality rates are higher in rural areas of Ghana than in urban areas (GSS, 2015). While infant mortality in Ghana decreased by about 36% (from 64 to 41 per 1000 live births) between 2003 and 2014, it increased by about 39% (from 33 to 46 per 1000 live births) in the UER within the same period (GSS, 2004; GSS, 2015). One potential issue is that prelacteal feeding, giving infants formula diluted with water from wells and boreholes before initiation of breastfeeding, is more common in the UER than other regions in Ghana (Kubreziga, 2012), which combined with increased agricultural intensification in the area due to the presence of largescale irrigation projects (FAO, 2005) may contribute to the contrary trends in infant mortality rates. Even though we are not aware of any published studies from the UER that explicitly link groundwater pollution and infant mortality, research from other areas has found relationships between groundwater pollution and infant mortality (Johnson et al., 1987; Von Ehrenstein et al.,

2006) and supplementation of infants' diet with water-based foods and infant disease risk (Popkin et al., 1990). In addition, there is no doubt that water pollution has concomitant negative health effects in the UER (Hunter, 1997), deprives the inhabitants of their livelihoods, and also has the potential to increase poverty levels due to increased health costs.

3. Theoretical Model

We use a double-bounded contingent valuation method (DBCVM) question format to elicit producer WTP for improved groundwater quality. Compared to the dichotomous choice format, the DBCVM increases the efficiency of the estimation of the WTP and is suitable for small sample sizes (Hanemann, Loomis and Kanninen, 1991). The DBCVM asks two dichotomous choice valuation questions and some studies find that it may have starting point bias or anchoring effects (Herriges and Shogren, 1996; McLeod and Bergland, 1999), and shift in the distribution of the WTP between the two valuation questions (Alberini, Kanninen and Carson, 1997). Starting point bias occurs when a respondent has an initial WTP, which they compare to the first DBCVM bid to determine whether they are willing to pay the amount proposed in the bid, but subsequently update their WTP based on the initial bid when responding to the second DBCVM bid. Shifts in the distribution of WTP can occur if there is a systematic shift in the WTP between the first and second questions. The shift is because of the incentive incompatibility of the second valuation question (Whitehead, 2002). We test and correct for these data concerns using methods developed in the literature (Herriges and Shogren, 1996; Alberini et al., 1997; McLeod and Bergland, 1999; Whitehead 2002; Chien, Huang and Shaw, 2005).

Following the standard DBCVM format, a farmer is presented with two bids. The level of the second bid is conditional on the first bid. If a farmer answered "yes" to the first bid, the second bid presented is higher than the first bid. If a farmer answered "no" to the first bid, the second bid presented is lower than the first bid. We thus have four possible outcomes with regard to the responses: "yes-yes", "yes-no", "no-yes" and "no-no", with their corresponding likelihoods represented as $\pi^{yy}, \pi^{yn}, \pi^{ny}$, and π^{nn}, respectively. Let B_{i1} represent the first bid the respondent is confronted with, B_{i2}^{l} which is lower than B_{i1} represents the second bid after "no" response, and B_{i2}^{u} is higher than B_{i1} and represents the second bid after a "yes" response.

3.1. Parametric Model

The conventional double-bounded contingent valuation model assumes that a respondent's true WTP does not vary across the two valuation questions (Alberini et al., 1997). This implies that the underlying WTP that generates the yes/no response to the first valuation question is equal to the underlying WTP that determines the response to the second valuation question $(WTP_{i1} = WTP_{i2})$ and that there is no anchoring of follow-up responses to the initial bid (Whitehead, 2002). A "yes" response to B_{i1} implies $WTP_{i1} \geq B_{i1}$, while a "no" response implies otherwise. A respondent whose WTP is not fixed may consider the initial bid as the benchmark for the "correct WTP", which would lead to anchoring or starting point bias in the follow-up bid responses. Ignoring the potential anchoring effect of the initial bid on responses to the follow-up questions may lead to biased estimates of the median and variance of the WTP (Herriges and Shogren, 1996).

Following Herriges and Shogren (1996), the WTP from the follow-up question in DBCVM is expressed as the weighted average of WTP_{i1} and the initial bid:

$$WTP_{i2} = (1 - \gamma)WTP_{i1} + \gamma B_{i1} \tag{1}$$

where $0 \leq \gamma \leq 1$, and measures the extent of anchoring. If $\gamma = 0$, there is no anchoring effect and $WTP_{i2} = WTP_{i1}$. If $\gamma > 0$, there is anchoring or starting point bias and $WTP_{i2} \neq WTP_{i1}$, while $\gamma = 1$ is the highest degree of anchoring and the respondent's $WTP_{i2} = B_{i1}$. Chien et al. (2005) also develop a test for starting point bias in DBCVM using bid set dummies, where each dummy identifies the initial bid in the set.

Following Alberini et al. (1997), the structural shift in the WTP amount is the coefficient on the dummy variable representing the second valuation question. The structural shift effects model is in the form:

$$WTP_{i2} = WTP_{i1} + \delta \tag{2}$$

where δ is the structural shift. A negative value of δ is an indication of nay-saying behavior, and yea-saying behavior if it is positive.

A combination of the Herriges and Shogren (1996) and Alberini et al. (1997) models represent the anchoring and shift effects model proposed by Whitehead (2002). Combining equations (1) and (2) into an anchoring and shift effects model yields:

$$WTP_{i2} = (1 - \gamma)WTP_{i1} + \gamma B_{i1} + \delta \tag{3}$$

When $\gamma = 0$ and $\delta = 0$, we have the conventional double-bounded model which implies (1) and (2) are restricted versions of (3).

4. Empirical Model and Estimation

We specify the parametric estimation of the double-bounded CVM model following Hanemann et al. (1991). The likelihood of a "yes-yes" response from a farmer is $\pi^{yy}(B_{i1}, B_{i2}^u) = \Pr(WTP_i \geq B_{i2}^u)$; for "no-no" response, the likelihood $\pi^{nn}(B_{i1}, B_{i2}^l) = \Pr(WTP_i \leq B_i^l)$; for "yes-no" response, $\pi^{yn}(B_{i1}, B_{i2}^u) = \Pr(B_{i1} \leq WTP_i \leq B_{i2}^u)$; and for "no-yes" response, $\pi^{ny}(B_{i1}, B_{i2}^l) = \Pr(B_{i1} \geq WTP_i \geq B_{i2}^l)$. Assuming respondents are utility maximizers and WTP is normally distributed, the log-likelihood function for estimating parameters of (3) is a combination of the following likelihoods[2]:

$$\pi^{yy}(B_{i1}, B_{i2}^u) = 1 - \Phi\left(\frac{B_{i2}^u - z_i'\beta - \gamma(DB_{i1}) - \delta D}{\sigma}\right) \tag{4}$$

$$\pi^{nn}(B_{i1}, B_{i2}^l) = \Phi\left(\frac{B_{i2}^l - z_i'\beta - \gamma(DB_{i1}) - \delta D}{\sigma}\right) \tag{5}$$

$$\pi^{yn}(B_{i1}, B_{i2}^u) = \Phi\left(\frac{B_{i2}^u - z_i'\beta - \gamma(DB_{i1}) - \delta D}{\sigma}\right) - \Phi\left(\frac{B_{i1} - z_i'\beta}{\sigma}\right) \tag{6}$$

$$\pi^{ny}(B_{i1}, B_{i2}^l) = \Phi\left(\frac{B_{i1} - z_i'\beta}{\sigma}\right) - \Phi\left(\frac{B_{i2}^l - z_i'\beta - \gamma(DB_{i1}) - \delta D}{\sigma}\right) \tag{7}$$

[2] See Hanemann et al. (1991) for derivations of parts of the likelihood function based on the response categories.

where $D = 0$ represents the first valuation question, $D = 1$ for the second valuation question, and DB_{i1} is interaction between D and the initial bid. For N respondents, where B_{i1}, B_{i2}^l, and B_{i2}^u represent the bids posed to the i[th] respondent, the log likelihood function for the estimation of the parameters of (3) can be written explicitly in the form:

$$lnL = \sum_{i=1}^{N}\{ w_i^{yy}\ln(1-\Phi\left(\frac{B_{i2}^u - z_i'\beta - \gamma(DB_{i1}) - \delta D}{\sigma}\right)) + w_i^{nn}\ln\Phi\left(\frac{B_{i2}^l - z_i'\beta - \gamma(DB_{i1}) - \delta D}{\sigma}\right) + w_i^{yn}\ln\left(\Phi\left(\frac{B_{i2}^u - z_i'\beta - \gamma(DB_{i1}) - \delta D}{\sigma}\right) - \Phi\left(\frac{B_{i1} - z_i'\beta}{\sigma}\right)\right) + w_i^{ny}\ln\left(\Phi\left(\frac{B_{i1} - z_i'\beta}{\sigma}\right) - \Phi\left(\frac{B_{i2}^u - z_i'\beta - \gamma(DB_{i1}) - \delta D}{\sigma}\right)\right)\} \quad (8)$$

where w_i^{yy}, w_i^{nn}, w_i^{yn}, and w_i^{ny} are binary-valued indicator variables, z_i represents farm and farmer characteristics with their corresponding coefficients, β, and σ is the scale parameter.

Following Whitehead (2002), we construct pseudo-panel data to account for the anchoring and shift effects in our models[3]. We estimate the model (Eq. 3), from the pseudo-panel data using an interval data approach (see Haab and McConnell, 2003) because it is computationally convenient and allows us to estimate directly an inverse Hicksian demand function in which the coefficients of the model are easy to interpret as marginal WTP of their associated regressors (see Cameron, 1988).

We first estimate the anchoring and the shift effects model using the full sample with scenario as a dummy variable, and then split the sample by scenario and estimate the

[3] See Whitehead (2002) for the details on how on to create the pseudo-panel data.

model for respondents exposed to health and environment scenarios separately. The population mean WTP is then calculated as in (9)[4]:

$$E(WTP) = \bar{Z}\hat{\beta} \tag{9}$$

where $\bar{Z}$ is the mean vector of the explanatory variables.

5. Data

The survey respondents comprise 503 randomly selected households from nine communities within and around Vea, Gowrie, and Nyariga in the Bongo district of Ghana. These communities form the majority of smallholder irrigation farmers under the Vea irrigation scheme. We used household information from the Bongo District Assembly to select the sample of households. We selected a minimum of 61 households from each community with a goal of interviewing 550 households. Five interviewers were assigned to interview these households and each interviewer interviewed 10 households per day for a period of 11 days in June 2016.

The interviewers were first trained on how to administer the questionnaires. The interviewers also practiced among themselves and pretested the questionnaires in the survey area to find out whether the questions were understood by the survey respondents. An interviewer first explained the reason for the survey to the head of household (HoH) or another adult, and proceeded with the survey if the person agreed to participate. Some selected households refused to answer the questionnaires or refused to answer certain questions, so our final dataset includes 503 households for a response rate of 91%.

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[4] The population mean can also be calculated by predicting and averaging the individual means. In our case, the results from this approach and that in equation (9) are similar.

The survey questionnaire elicited socioeconomic characteristics, farm attributes, households' water sources and the respondents' perceptions about groundwater pollution. The valuation question followed immediately after the description of the contingent valuation scenario. We randomized the two scenarios and four bid levels among the respondents. One scenario emphasized groundwater pollution while the other scenario emphasized health risks of groundwater contamination. The bid levels were determined from focus groups and pretest surveys and are presented in Table 1. The scenarios and the valuation questions are shown below:

I would like to ask you questions to help us understand your value of groundwater protection. The use of nitrogen fertilizers such as Nitrogen Phosphorus Potassium (NPK) can lead to pollution of the groundwater with nitrates through leaching. Kubreziga (2012) found that levels of nitrates in unregulated water sources in the Upper East region exceeded WHO's recommended levels for consumption. Either ***"Excess nitrates are known to contaminate groundwater"*** *or "****Excess nitrates are known to pose significant health risk to consumers in addition to being one of the main causes of acquired methemoglobinemia (a condition that is harmful to babies)."*** *We want to know how much you are willing to pay for fertilizers that are equally productive and are easily absorbed by crops, thereby reducing the leaching of nitrogen into groundwater.*

Now, suppose you have a choice of two fertilizers that provide the same nutrients (NPK) to your crops. Fertilizer A can cause groundwater contamination due to leaching. Fertilizer B is easily absorbed by plants, which implies fertilizer B does not leach as much and does not contaminate groundwater.
1. Would you use fertilizer B if it costs ………GHC/acre more than fertilizer A?
….. Yes (ask question 2 with the next higher bid)
…. No (ask question 2 with the next lower bid)

[Insert Table 1 about here]

The summary statistics of selected variables are in Table 2. About 65% of the respondents are male, the average age of respondents is 44.37 years, and 60% have no formal education. About 18% of the respondents received some education but did not complete high school (primary/middle/junior high level of education) and 21.9% have a high school level of education or above. Sources of domestic water also varied. Respondents could indicate that they use water from more than one source, so percentages add up to more than 100%. About 26% of households in the population use water from hand-dug wells for domestic purposes, 9.3% use water from pump-wells, 7.4% use water from pipe, 21.5% use water from "bulga" (shallow dug-outs at the banks of dams), and 90.1% of the population use borehole water.

The average total farmland (within and outside the Vea irrigation scheme) owned by a respondent is 5.95 acres, and the average number of bags of inorganic fertilizer used during the 2014/2015 farm year was reported to be 6.6 bags (1 bag = 50kg). Not all farmlands were cultivated to maize or rice and some were not even cultivated at all in the previous year. The average fertilizer application rate for the previous year is a little over one bag per acre. About 84% of the farmers report that they used chemical fertilizers or both chemical and organic fertilizers during the previous farm year. Just over half of the farmers, 52.3%, said they are aware that groundwater can be contaminated by nitrates from chemical fertilizers. The average farm income is GHC 1235.06 under the Vea Irrigation scheme for the previous farm year.[5] Average total income of a household is GHC 2044.69 and average nonfarm income is GHC 810.52. Farmers reported other assets such as livestock and harvested crops that increase their income levels when sold. The average number of years of farming under the scheme is 11.6.

[Insert Table 2 about here]

[5] One GHC is approximately 0.25 US dollars.

6. Results and Discussion

Table 3 presents the distribution of responses by bid level for the full sample. The distribution of responses by scenario is presented in Table 4. The DBCVM regression results for the anchoring and shift effects models from the full sample, the environmental scenario and the health scenario subsamples are presented in Table 5. The last column shows the test statistic for the test for equality of the coefficients of the two scenarios. Both the anchoring, γ, and shift, δ, parameters are significant at the 1% level in all three models. From the full sample regression, the significant variables are *spouse of HoH, fertilizer quantity, vea income, environmental scenario, hand-dug well, borehole, pipewater, high school or more,* and *sex,* in addition to the anchoring and shift parameters. The *spouse of HoH* variable is significant at the 1% level with a coefficient estimated to be -36.92 GHC. This implies that heads of households have higher WTP to protect groundwater than their spouses and other household members. This may be because heads of households in the survey area are responsible for the economic well-being of the household members and for management of household finances. The *fertilizer quantity* variable is significant at the 5% level and shows that an increase in 1 bag of inorganic fertilizer used decreases a farmer's WTP to protect groundwater by GHC 0.488. Although the payment vehicle was based on a per-acre charge, it's possible that farmers who use more fertilizer expect to have a higher cost associated with the fee. Farmers incur costs in the use of inputs such as fertilizer in production and farmers who use fertilizer should really be willing to pay less to protect groundwater because they want to minimize costs. The *environmental scenario* variable is also significant at the 1% level and indicates that WTP of respondents posed with the health scenario is higher than that of those posed with the environmental scenario by GHC 14.683. This implies that respondents are more concerned about the negative health externalities of groundwater contamination than the environment impacts.

Variables representing domestic water sources, including *hand-dug well, borehole,* and *pipe water* are each significant at the 1% level. The parameter estimate for *hand-dug well* implies that WTP of households who use water from hand-dug wells for domestic purposes is higher than those who do not by GHC 16.24. The WTP of households who use borehole water is higher by GHC 14.40, while that of households who use pipe water is lower by GHC 35.89. These findings make sense because hand-dug wells and boreholes provide groundwater and users therefore have strong motivation to protect the quality of water coming from those sources. In contrast, pipe water is treated water, so users who have no bequest or nonuse values for groundwater, may not be willing to pay more to preserve groundwater. The *high school or more* variable is significant at 1% level and implies that WTP of farmers with high school or above education level is higher than the WTP of farmers with education below high school by GHC 10.67. Some of the previous studies on groundwater valuation find education to positively impact WTP (Jordan and Elnagheeb, 1993), while others find it has no impact on WTP (Shultz and Linsay; 1990; Stenger and Willingner, 1998; Lichtenberg and Zilberman, 1999). The *sex* variable is significant at the 1% level and implies that a male farmer's WTP is GHC 8.89 lower than that of a female farmer, which is similar to results from other studies (Jordan Elnagheeb 1993; Stenger and Willingner, 1998).

The anchoring parameter is estimated to be $\gamma = 0.638$ and is significant at the 1% level. This indicates high degree of anchoring in the WTP responses. The shift parameter is estimated to be $\delta = -34.40$ and is also significant at the 1% level, suggesting that nay-saying bias is present in the WTP responses. The shift parameter shows that the second valuation question biases the population WTP downward by GHC 34.40. After correcting for the behavioral biases in the WTP responses, the population mean WTP from the full sample model is calculated as GHC 69.13 and its 95% confidence interval (CI) is [66.72, 71.53]. A majority of the farmers grow maize and rice during the wet season, which are the two main crops grown in this area that require chemical fertilizer application. The average number of combination of maize and rice acres reported for the 2014/2015 farm year is 2.43 acres. Given the confidence interval of the mean WTP from the full sample, and the maize and rice average acres of 2.43, we calculate that farmers are willing to pay 7.9 to 8.5% of the average annual income to protect groundwater. Farmers also reported that they have assets including livestock and harvested crops they sell to add to their incomes. So, incomes of these farmers can be higher than those reported depending on whether they sell their assets.

Farmers received either the environment scenario or the health scenario survey questionnaires. We estimate WTP by scenario to find out which scenario yields higher WTP. The results are presented in columns three and four in Table 5. The mean WTP from the environmental scenario model is GHC 57.36 and its 95% CI is [54.20, 60.53]. The mean WTP from the health scenario model is 78.59 with 95% CI as [75.02, 82.16]. We tested for the equality of the mean WTP between the two scenarios models using a t-test and rejected the null that they are equal at the 1% level, which is evidenced by the non-overlapping CIs. We have similar results in terms of the significance of the anchoring and the shift effects parameters in the environmental and health scenario models. Both the anchoring and the shift effects parameters are significant at the 1% level in each model. The significance of the variables in the anchoring and shift effect model by scenario are similar overall except that the *fertilizer quantity* variable is significant at 5% in the health scenario model but not in the environmental scenario model, while *pump well* is significant at 5% in the environmental scenario model but not significant in the health scenario model.

To further compare the environmental and the health scenario models, we tested for the equality of the coefficients of the individual variables between the models and the vector of coefficients as a whole using seemingly unrelated regression estimation (see StataCorp, 2015). These test results are also presented in column five in Table 5. For each of *pump well, pipe water, some schooling, and the shift effect* variables, we rejected the null that the coefficients do not differ at 10% level or less. But for the rest of the variables, we fail to reject the null that the coefficients do not differ, even at the 10% level. We also rejected the null that the vector of coefficients does not differ across the two models at the 1% level.

[Insert Table 3 about here]

[Insert Table 4 about here]

[Insert Table 5 about here]

6.1. Robustness Test: Alternative Test of Starting Point Bias

We also estimate the Chien et al. (2005) model as an additional test for starting point bias by adding bid set dummies that represent the initial bids in each set in the estimation of the conventional DBCVM model. The regression results of the DBCVM models with the bid set dummies are in Table 6. All the bid set dummies in all the models are significant at the 1% level except in the environmental scenario model where the second bid set dummy is significant at the 10% level. These results also suggest that starting point bias or anchoring effects occur in the WTP responses.

[Insert Table 6 about here]

6.2. Robustness Test: Non-parametric Model

The mean WTP from the non-parametric estimation, also called Kaplan-Meier-Turnbull (KMT) estimator, represents the lower bound on the mean of the WTP distribution (Hanemann and Kanninen, 2001; Carson and Hanemann, 2005). A non-parametric approach such as the Turnbull estimator is also an ex post approach to overcoming hypothetical bias in stated preference surveys (Loomis, 2014). For *I* distinct values representing the initial bids used in the DBCVM, the initial bid is B_{i1} and the follow-up bids are B_{i2}^{l} if the farmer said "no" to the initial bid, and B_{i2}^{u} if the farmer said "yes" to the initial bid, Following Hanemann and Kanninen (2001), two artificial bids, $B_0 \equiv 0$ and $B_{I+1} \equiv \infty$ are added to the original follow-up bids. The log-likelihood function for non-parametric estimation of WTP from double-bounded data is expressed in terms of the *I* distinct values representing the initial bids B_{i1} and the follow-up bids B_{i2}^{l} and B_{i2}^{u} including the artificial bids. It is in the form:

$$lnL = \sum_{i=1}^{I+1} N_i \ln[G_{WTP}(B_{i1}) - G_{WTP}(B_{i1-1})] \equiv \sum_{i=1}^{I+1} N_i \, ln\pi_i \qquad (10)$$

where $G_{WTP}(.)$ is the WTP distribution function and N_i is the number of farmers for whom $B_{i1-1} < WTP \leq B_{i1}$. The π_i represents the change in distributions of the WTP. To estimate $G_{WTP}(.)$ non-parametrically, Hanemann and Kanninen (2001) define $S_i \equiv G_{WTP}(B_{i1}) = \Pr\{a\ farmer\ says$ 'no' to $B_{i1})$. Following Carson and Steinberg (1990), and Carson et al. (1994) the Kaplan-Meir-Turnbull (KMT) estimator can be obtained by defining the survival probability $P_i = 1 - S_i \equiv 1 - G_{WTP}(B_{i1}) = \Pr\{a\ farmer\ says$ 'yes' to $B_{i1})$. The survival probabilities represent the probabilities of accepting the upper bound and they must form a monotone non-increasing sequence in the estimation of $\hat{P}_i$. Pool adjacent violators algorithm (PAVA) is applied when the probabilities of accepting the upper bound fail to form a monotone non-increasing sequence. The PAVA is a procedure to ensure the sequence of $\hat{P}_i$ is non-increasing (See Ayer et al., 1955). The Kaplan-Meier-Turnbull estimate of the mean WTP is then calculated using the formula in (11) proposed by Hanemann and Kanninen (2001).

$$E(WTP) = \sum_{i=1}^{I}(\hat{P}_i - \hat{P}_{i+1})B_{i1} \equiv \sum_{i=1}^{I}\hat{\pi}_i B_{i1} \quad (11)$$

where $\hat{P}_i$ is the estimated survival probability and $\hat{\pi}_i$ is the estimated change in survival probability. Table 7 presents the KMT estimates using the double-bounded data. The mean WTP is calculated as GHC 60.25 for the full sample. The KMT estimate is the lower bound of the distribution of the WTP which is less than the parametric estimate of GHC 69.13 from the full sample.

[Insert Table 7 about here]

7. Conclusions

Rural households' reliance on groundwater in Ghana is inevitable because they lack access to consistently safe water for domestic use. Hang-dug wells and boreholes are the most common sources of groundwater in these rural areas but they are generally unregulated and may be contaminated by pollutants including nitrates from chemical fertilizers. This paper estimates the willingness of smallholder irrigation farmers under the Vea irrigation scheme to pay for groundwater protection using two contingent valuation scenarios: environmental and human health. We use scenarios that frame information differently to investigate how framing affects respondents' willingness to pay (WTP) for groundwater protection. We employ the double-bounded contingent valuation method (DBCVM) model that accounts for anchoring and shift effects in DBCVM responses.

The mean willingness to pay from the full sample is about GHC 69 with 95% CI of [66.72, 71.53], which suggests that mean WTP to protect groundwater ranges from about 7.9% to 8.5% of the average annual income of the farmers based on 2.43 average acres of maize and rice. The mean WTP from the health scenario subsample is about GHC 79 and that from the environmental scenario subsample is about GHC 57. Previous studies find differences in mean WTP based on information provided to respondents about the resource being valued (Bergstrom, Dillman and Stoll, 1985; Samples, Dixon and Gowen, 1986; Randall, 1990). In addition to the informational content of the scenario, farmers' WTP to protect groundwater in the study area depends on whether the farmer is the head of a household, the quantity of fertilizer used, income from farming, sources of water for domestic use (hand-dug well, borehole, pump well, pipe water), level of education of respondent, and sex of respondent. Farm income, water use from hand-dug well, borehole, pump well, and level of education each has a positive impact on farmers' WTP to protect groundwater while the environmental concern scenario, being a spouse of head of household, quantity of fertilizer used, water use from pipe, and being a male each has negative impact on WTP to protect groundwater. Jordan and Elnagheeb (1993) also find that women in addition to younger residents have higher WTP than others.

We also employ a nonparametric approach — the Turnbull estimator — as an ex post approach to overcoming hypothetical bias in stated preference surveys (Loomis, 2014) in the estimation of mean WTP. We derive Kaplan-Meier Turnbull (KMT) estimates for the double-bounded data using the full sample and find the mean WTP to be GHC 60 which represents the lower bound of the WTP distribution.

Our survey results confirm the reliance of rural households in Ghana on groundwater for domestic purposes. We find that 90% of the households in the study area use water from boreholes for their domestic purposes. About 26% of households in the population use water from hand-dug wells, 9.3% use water from pump-wells, only 7.4% have access to piped water, and 21.5% use water from "bulga" (shallow dug-outs at the banks of dams).

In summary, the results from this study indicate that farmers do value groundwater quality, particularly if their households depend on groundwater for domestic uses. Additionally, farmers exposed to information about the human health effects of groundwater pollution are willing to pay more than those exposed to information about effects of groundwater pollution on the environment. These findings suggest that future groundwater policies in the area should take into consideration impacts of agricultural production on groundwater quality and the associated impacts on human health. Due to a lack of resources to enact, enforce, and monitor socially optimal fertilizer policies that protect groundwater in developing countries, our findings suggest that if countries have to rely on voluntary action to prevent groundwater pollution, understanding how the framing of information affects willingness to voluntarily undertake costly actions is critical to motivate action from farmers.

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TABLES AND FIGURES

Table 1 Alternative bids (GHC)

B_{i1}	B_{i2}^{l}	B_{i2}^{u}
20	10	45
45	20	75
75	45	100
100	75	120

Table 2 Summary Statistics of Explanatory Variables

Variable	Obs.	Mean	Std. Dev.		Obs.	Mean	Std. Dev.
Water sources:				**Socio-demographic**:			
Hand Dug Well	503	0.262	0.440	Head of Household (HoH)	501	0.794	0.405
Pump Well	503	0.093	0.291	Spouse of HoH	501	0.146	0.353
Pipe Water	503	0.074	0.261	Other	501	0.060	0.238
Borehole	503	0.901	0.300	Male	497	0.654	0.476
Bulga	503	0.215	0.411	Age	486	44.38	12.36
				No formal education (0/1)	503	0.602	0.490
Farm and knowledge:				Some education (0/1)	503	0.179	0.384
Total Land (acres)	503	5.949	4.024	High School or above (0/1)	503	0.219	0.414
Vea Income (GHC)	454	1235.06	1152.69	Number of Family Members over age 5	471	8.408	5.844
Years Farming in Vea Irrigation Scheme	432	11.616	8.593	Number of Family Members with Income	478	2.611	1.860
Fertilizer Type Used (1 if inorganic; 0 else)	485	0.839	0.754	Non-farm Income (GHC)	445	810.52	1002.13
Bags of Fertilizer Used (in last farming year)	417	6.595	6.702	Total Income	490	2044.69	1325.87
Knowledge of Groundwater Contamination (1 if yes)	503	0.523	0.500				

Table 3 Number and % of respondents (N=500 surveys)

Initial Bid	Yes/Yes	Yes/No	No/Yes	No/No	Total
20	90 (18.0)	64 (12.8)	43 (8.6)	4 (0.8)	201
45	41 (8.2)	28 (5.6)	30 (6.0)	5 (1.0)	104
75	33 (6.6)	34 (6.8)	15 (3.0)	16 (3.2)	98
100	16 (3.2)	42 (8.4)	21 (4.2)	18 (3.6)	97
Total	180 (36.0)	168 (33.6)	109 (21.8)	43 (8.6)	500

Note: Values in parentheses are percentages.

Table 4 Number and Percent of Respondents by Scenario (N=500 surveys)

Initial Bid	Yes/Yes	Yes/No	No/Yes	No/No	Total
			Environment Scenario		
20	59 (11.8)	45 (9)	33 (6.6)	3 (0.6)	140
45	35 (7)	17 (3.4)	22 (4.4)	2 (0.4)	76
75	2 (0.4)	6 (1.2)	1 (0.2)	3 (0.6)	12
100	3 (0.6)	5 (1)	2 (0.4)	2 (0.4)	12
Total	99 (19.8)	73 (14.6)	58 (11.6)	10 (2)	
			Health Scenario		
20	31 (6.2)	19 (3.8)	10 (2)	1 (0.2)	61
45	6 (1.2)	11 (2.2)	8 (1.6)	3 (0.6)	28
75	31 (6.2)	28 (5.6)	14 (2.8)	13 (2.6)	86
100	13 (2.6)	37 (7.4)	19 (3.8)	16 (3.2)	85
Total	81 (16.2)	95 (19)	51 (10.2)	33 (6.6)	

Note: Values in parentheses are percentages.

Table 5 Regression Results of DBCV Models

	Full Sample	Environmental Scenario	Health Scenario	Tests for Equality of Coefficients
Variable	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)	Chi2
Spouse of HoH	-36.92 (3.852)***	-33.14 (4.562)***	-39.84 (6.015)***	0.91
Not HoH or Spouse	0.863 (4.659)	-3.266 (6.088)	4.970 (6.484)	1.12
Total Land	-0.368 (0.386)	-0.736 (0.528)	0.145 (0.526)	1.50
Fertilizer Quantity	-0.488 (0.203)**	-0.363 (0.281)	-0.605 (0.274)**	0.51
Vea Income	0.007 (0.001)***	0.006 (0.002)***	0.006 (0.002)***	0.05
Nonfarm Income	0.0004 (0.001)	-0.002 (0.002)	0.002 (0.002)	1.74
Environmental Scenario	-14.69 (2.530)***			
Hand Dug Well	16.24 (2.997)***	13.06 (3.880)***	15.91 (4.151)***	0.23
Pump Well	2.465 (4.021)	12.33 (5.763)**	-4.848 (5.393)	5.52**
Borehole	14.40 (4.385)***	17.91 (5.738)***	12.90 (6.208)**	0.45
Pipe Water	-35.89 (6.682)***	-20.85 (7.993)***	-49.96 (11.341)***	2.82*
Bulga	4.014 (2.867)	4.026 (3.775)	3.454 (4.007)	0.01
Some Schooling	4.403 (3.235)	-2.412 (4.298)	8.120 (4.568)*	2.75*
High School or More	10.67 (3.332)***	15.65 (4.547)***	8.950 (4.484)**	0.98
Sex (1 = Male, 0 = Female)	-8.886 (2.722)***	-13.84 (3.548)***	-5.149 (3.809)	2.78*
Age	-0.030 (0.103)	0.015 (0.128)	-0.034 (0.151)	0.05
Constant	67.45 (7.456)***	47.80 (8.935)***	70.27 (10.865)***	2.48
γ = anchoring effect	0.638 (0.057)***	0.788 (0.094)***	0.730 (0.077)***	0.27
δ = shift effect	-34.40 (3.807)***	-28.83 (4.446)***	-50.57 (6.146)***	10.47***
Log likelihood	-859.883	-387.765	-441.412	
Wald Chi2	612.52***	277.70***	263.05***	104.65***
Mean WTP (GHC)	69.13 (1.23)	57.36 (1.61)	78.59 (1.82)	
95% CI	[66.72 71.53]	[54.20 60.53]	[75.02 82.16]	
Obs.	750	356	394	

Note: *** is significance at 1% level, ** is significance at 5% level, and * is significance at 10% level. The omitted categories are: ‘Head of household’ and ‘No education’.

Table 6 Regression Results of DBCV Models with Bid Set Dummies.

	Full Sample	**Environmental Scenario**	**Health Scenario**
Variable	Coeff.(Std. Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err.)
Spouse of HoH	-24.861 (3.373)***	-23.517 (4.321)***	-27.610 (5.263)***
Not HoH or Spouse	2.908 (4.249)	0.487 (5.984)	4.670 (6.076)
Total land	-0.145 (0.335)	-0.541 (0.500)	0.390 (0.461)
Fertilizer Quantity	-0.205 (0.179)	-0.030 (0.271)	-0.420 (0.244)*
Vea Income	0.005 (0.001)***	0.005 (.001)***	0.005 (0.001)***
Nonfarm Income	0.002 (0.001)	0.0001 (.002)	0.003 (0.001)
Environmental Scenario	-0.526 (2.488)		
Hand-dug Well	12.409 (2.534)***	10.801 (3.544)***	12.095 (3.551)
Pump Well	6.945 (3.582)*	13.377 (5.682)**	3.468 (4.803)
Borehole	18.143 (3.928)***	15.026 (5.524)***	21.381 (5.674)***
Pipe Water	-32.580 (5.564)***	-25.266 (7.625)***	-40.020 (9.084)***
Bulga	3.370 (2.515)	5.675 (3.669)	1.416 (3.511)
Some Schooling	1.092 (2.839)	-0.585 (4.115)	0.831 (4.109)
High School or More	11.668 (2.853)***	16.492 (4.294)***	8.980 (3.846)**
Sex (1 =Male, 0 = Female)	-4.610 (2.351)*	-8.043 (3.352)**	-2.156 (3.317)
Age	0.022 (0.089)	0.039 (0.121)	0.070 (0.131)
Constant	60.775 (6.693)***	61.488 (9.876)***	54.876 (9.763)***
First Bid Set	-44.309 (3.059)***	-40.086 (5.804)***	-44.742 (3.920)***
Second Bid set	-17.366 (3.537)***	-11.874 (6.127)*	-20.380 (5.357)***
Fourth Bid Set	24.510 (3.176)***	31.631 (8.425)***	23.192 (3.569)***
Log likelihood	-350.319	-160.137	-180.441
Wald Chi2	987.78***	356.92***	447.67***
Mean WTP (GHC)	65.04 (1.05)	53.24 (1.51)	75.62 (1.55)
95% CI	[62.97 67.11]	[50.28 56.20]	[72.58 78.66]
Obs.	375	178	197

Note: *** is significance at 1% level, ** is significance at 5% level, and * is significance at 10% level.
The omitted categories are: 'Head of household', 'No education', and 'Third bid set dummy'.

Table 7 Kaplan-Meier-Turnbull Estimation for the double-bounded data (N=500)

Lower bound (B_i)	Upper bound (B_{i+1})	Survival probability ($\hat{P}_i$)	Change in density ($\hat{\pi}_i = \hat{P}_i - \hat{P}_{i+1}$)	$\hat{\pi}_i B_i$
0	10	0.9894	0.0106	0
10	20	0.8753	0.1141	1.414
20	45	0.6499	0.2254	4.508
45	75	0.5173	0.1326	5.967
75	100	0.3224	0.1949	14.618
100	120	0.0889	0.2335	23.350
120	∞	0	0.0889	10.668

E(WTP) = 60.25