Research article

Analysis of households' willingness to pay for a renewable source of electricity service connection: evidence from a double-bounded dichotomous choice survey in rural Ethiopia

Birku Reta Entele*

Department of Technology and Innovation Management, Adama Science and Technology University, P.O.box 1888, Adama, Ethiopia

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ABSTRACT

Getting access to electricity services for domestic consumption is still a luxury service in the rural areas of developing countries. For instance, about 55 percent of the total population do not have access to electricity service in Ethiopia. To alleviate the problem, the government of Ethiopia is intensively investing on hydroelectric dam construction so as to increase the coverage of electricity. However, the grid-line electricity supply in the scattered settlements of rural households of Ethiopia poses a challenge for connection. This study investigated households' preference for renewable source of electricity service connections and estimated potential willingness to pay for the services by considering solar PV electricity in addition to the grid-line. In this survey, 220 rural households were sampled from Hexosa (Harbe) and Boset (Xiyyo) districts in Ethiopia using systematic sampling methods. The result estimated by using bivariate probit model reveals that the median willingness to pay alone is not sufficient to recover the cost of connection of electricity service. However, among the two sources of renewable electricity services, households preferred grid line to solar electricity services irrespective of the payment scheme. Monthly instalment-based payment is more convenient for the rural household than lump sum connection cost payment regarding the payment scheme. Furthermore, the households' income level, level of education, age, location and amount of initial bid prices are important variables in determining the scale of households' willingness to pay for connection of electricity service. Therefore, based on the findings of the study, the following policy suggestions have been forwarded: there should be provision of electricity service that is suitable and preferred by the rural households and the community shall get various options of payment modalities.

1. Introduction

The demand for electricity consumption and economic growth rate are constantly increasing with a compound annual growth rate of 2.8 percent and 4.0 percent per year respectively from 2008 to 2012 globally (Kim et al., 2015). However, currently about 12.65 percent of the world population have no access to electricity. Yet in Sub-Saharan Africa, 57.2 percent of the population have no access to electricity services according to the Energy Information Administration and Energy Department (2015). According to the World Bank data source (2016) only about 45 percent of the total population of Ethiopia have access to electricity of which 26.5 percent are rural dwellers and 85.4 percent are urban dwellers.

In Ethiopia, access to grid line may not necessarily imply reliable electricity service connection. According to the Ministry of Water Irrigation and Electricity report of Ethiopia (2017), only about 25 percent of the households have connectivity with 100 kWh/annual per capita electricity consumption. This implies that a large percentage of population particularly in the rural areas still rely on non-renewable and unclean energy sources such as charcoal, wood, biomass, kerosene and other petroleum product gases to meet their basic needs. However, these sources of energy create social, economical and environmental hazards. Lighting services obtained as such are inefficient and often costly to the

* Corresponding author.

E-mail address: birku.reta@astu.edu.et.

1 https://data.worldbank.org.

2 https://www.mowie.gov.et/partners/ethiopian-ministry-water-irrigation-and-electricity.
users. Besides the traditional kerosene, paraffin, and wood based lighting cause indoor and outdoor pollution and degrade the environment besides limiting productivity.

To alleviate these problems, the government of Ethiopia has set a trajectory for rural electrification program to be catered by grid and off-grid electricity sources (National Planning Commission, 2015). This is because a modern energy, particularly electricity for household use provides an improved welfare status when households are able to engage in additional income generating activity. This plan can be feasible for Ethiopia as it has huge potentials for renewable electricity generation of up to 45,000 MW from hydro plants and 5.5 kwh/m2/day from solar energy (Asress et al., 2013). Accordingly, if utilised optimally, this can alleviate the current energy shortage in the country and thereby improve the process of rural electrification.

By the year, 2015 about 98.60 percent of the total electricity production in Ethiopia was from renewable energy sources and of this about 90.80 percent was from hydropower (Kebede, 2015). Currently, the government of Ethiopia is currently constructing the Great Renaissance Dam hydropower plant on the Nile River, which is expected to generate 6000 MW electric power, and boost the total electricity production from hydropower (Taye et al., 2016). The construction of this hydroelectric power is expected to enhance the provision of electricity and narrow down the high demand. The prevailing high demand is due to the imbalance between electricity users’ demand which results from rapid economic growth of the country and the supply as a (Nyasha et al., 2018).

As a trend, the grid based electricity distribution network is perceived to be less likely to outreach the rural community because of their scattered settlement patterns. The grid electricity is recommended for densely populated areas because of economies of scale distribution whereas, the off-grid systems like photovoltaic systems cater for relatively less populated and scattered areas (Bekele and Tadesse, 2012). The identification of consumer preferences and their affordability level for service connection and consumption is essential for efficient and proper planning of low-income countries. Currently the government of Ethiopia is intensively promoting rural electrification program towards green energy sources. The main technologies being promoted for the success of the aforementioned project is solar PV system in addition to mini grid electricity sources (Kebede, 2015).

However, before allotting budget and forwarding policy directions, a thorough survey of the sustainability of a given rural green electrification program, the preferences of the community, affordability level of the rural households and the determinants for adopting this green energy sources must be carried out. A few studies have been conducted on the demand for electricity connection in general, and energy choices and preferences in particular in the Northern part of Ethiopia. For instance, Gebreziabher et al. (2012) investigated about urban household energy switch behavior from traditional fuel based to modern renewable energy sources in Northern Ethiopia. However, the result revealed that such an energy transition could be realized only if the majority of users can maintain appropriate cooking appliances or stove technologies. But the study failed to identify to which modern electricity type consumers would like to switch from the existing traditional fuels.

Another study by Lay et al. (2013) explored the factors affecting household choices of fuels including solar home system in Kenya. This study made it evident that household income and education level significantly affects solar home system adoption. Furthermore, it also reveals that in the area with high prevalence of solar home system, people has higher likelihood of adoption. However, there is lack of studies on investigation of the demand for renewable sources of electricity services in the context of rural households of Ethiopia. Hence, this study is meant to bridge the gap of determining the demand for renewable energy sources among the rural households. Based on the current diffusion rate and broader availability, the study exclusively focuses on the preference for electricity services from grid line and solar PV system, which are a potential source of electricity services for the rural electrification projects in the country.

The current study investigate and assesses preferences for a different source of renewable electricity and estimate rural households' Willingness to Pay (WTP). The study also explored the value that consumers place on each electricity service source by investigating the following specific objectives: (1) to estimate households' Willingness to Pay (WTP) for grid electricity and photovoltaic (solar) electricity connections; (2) to identify socio-economic and demographic factors that determine the WTP for a rural household's electricity connection options; (3) to see whether household WTP is large enough to recover the cost of investments in each type of electricity connections.

The study is organized as follows: the following section presents a brief review of the literature, which summarizes and critiques previous works related to green energy demand. Then, the third section is data and methodology part which deals with how data was collected, Contingent valuation hypothetical scenarios, and methods of analysis. The fourth section deals with results and discussion of the study and finally the fifth section deals with the conclusion and policy implications.

2. Related literature review

There is a growing body of literature on energy demand estimation and household willingness to pay in both developed and developing countries. For instance, the study conducted by Bhandari and Jana (2010) investigates consumers' preference for different types of solar photovoltaics electricity sources in rural areas of India. By considering the stand-alone solar PV for every house and the mini-grid solar PV for few households, the study exhibited heterogeneity in behavioural pattern of household characteristics, which was explained in terms of flexibility in use and cost factor between the two systems. In addition, their study revealed that the higher the household expenditure on kerosene, the more the willingness to adopt solar electricity connection. However, their study exclusively focuses on electricity from solar PV, which lacks choice diversification for rural consumers of India. Had the consumers been provided with more alternative sources of electricity supply, they could have revealed more appropriate preferences, which could be more or less feasible.

Bergmann et al. (2008) in Scotland conducted studies on the preferences of renewable energy among urban and rural households using choice experiment methods. The study concludes that there is a difference among rural and urban households concerning renewable energy preferences, which depends on sources of energy considering trade-off between employments versus environment. However, the study did not focus on the preference of renewable electricity supply within a group that share similar socio economic setup, rather it compared the preference between two groups with different socio economic set up that is urban versus rural towards the renewable energy demand. It is obvious that these two groups could reveal different preference based on their socio economic and alternative availability context. Another study by Ek (2005) investigates consumers' attitudes towards wind power electricity generation sources. The result reveals that consumers' attitudes towards wind power electricity decreases with age and income whereas those who have environmental concern have shown positive attitude towards green electricity. However, the study could not compare preferences towards different renewable energy sources; rather it just exclusively focuses on wind power electricity. Hence, the consumers' attitude towards wind power electricity does not necessarily represent the consumers' attitude towards renewable source of electricity in general. This is because of the fact that attributes of energy from wind power can be different from that of solar PV, mini
hydro, nuclear, and other sources. Hansla et al. (2008) also investigates psychological attitudes towards green electricity demand among Swedish electricity consumers. Thus, the study revealed that consumers who have positive attitudes for green electricity valuing environmental cleanliness have more willingness to pay for the service and have less WTP with cost attributes. However, the study failed to identify which green electricity sources it refers to. The researcher presumes that, it refers to all sources of green electricity in general, but it could have been better if the source for this green electricity were properly identified to determine its policy implication.

Borchers et al. (2007) investigates consumer preference for different sources of green energy in the USA. The study considered solar, wind, biomass and farm methane energy sources and the consumers' willingness to pay for all sources of energy. The result revealed that consumers have willingness to pay for all green electricity and preferred solar electricity compared to wind, biomass and farm methane. However, the findings of this study may not work in the case of developing countries where alternative sources of electricity are not available.

Bergmann et al. (2006) investigates consumer preference for renewable energy investment attributes using choice experiment methods to estimate consumer value preference. The study considers hydro, wind, biomass energy alternatives with landscape, wildlife and air quality as external attributes. The result reveals the presence of difference in preferences among urban versus rural, and among high-income versus low-income consumers. However, the alternatives available in this study are not complete and comprehensive. For instance, the inclusion of solar PV, nuclear, and geothermal source of energy may change the aforementioned result, which can lead to different conclusion.

Similarly, a study by Yoo and Kwak (2009) explores consumers' WTP for green electricity in South Korea. The study proposed green electricity production increment from 0.2% to 7% of total energy supply and then tried to measure consumers' willingness to pay for increment in share of the green electricity. The study found significant WTP for the green energy proposed in South Korea. However, it failed to pinpoint the attributes for which the consumers' value green electricity. In fact, the preference towards environmental friendly source of energy is mentioned, but this may not be the only attribute that consumers unanimously value. There could be many individual and alternative attributes that determine consumer preferences for renewable source of energy, and hence the study was supposed to explain some of those factors. Another study by Ma et al. (2015) confirms that consumers have WTP for modern electricity that generated from renewable sources. Using a meta-data regression analysis, the study reveals that consumers have higher WTP for electricity generated from wind, solar or common renewable energy sources than that of biomass or hydropower. However, in a meta-regression analysis, it focuses only on how the variation in WTP shows differences across the population leaving other factors such as variation because of study design (which includes survey design, administration, and model specification) aside. It concludes that factors like renewable energy type, consumers' socio economic profile and energy consumption pattern have less impact on the variation of willingness to pay for renewable energy than the attributes of the design. This may need further confirmation by other studies in different socio economic context.

Another study by Lay et al. (2013) explored the factors affecting household choices of fuels including solar home system in Kenya. This study made it evident that household income and education level significantly affects solar home system adoption. Furthermore, it also reveals that in the area with high prevalence of solar home system, people has higher likelihood of adoption. However, this study was limited to solar home system only and it is difficult to understand comprehensive preferences of households' choices for lighting. Study by Gebreezgiabher et al. (2012) investigates urban household energy switch behaviour from traditional fuel based to modern renewable energy sources in Northern Ethiopia. However, the result revealed that such an energy transition is on the adoption of appropriate cooking appliances or stove technologies by the majority of users. This study failed to identify to which modern electricity type consumers would like to switch from the existing traditional fuels. In the real context of Ethiopia, renewable electricity is provisioned from hydro and solar PV, but the study did not address to which of these electricity sources the consumers wish to switch given the condition stated in the finding.

Therefore, by considering the real situation of rural households in Ethiopia wherein the majority of the rural household mainly depends on non-renewable energy sources such as firewood and kerosene and the government intensively promotes rural electrification program, this study investigates rural households' preferences and WTP for gridline and photovoltaics electricity service connection using different payment schemes. The finding of the study may assist in policy and strategy making with regard to renewable energy sources for rural electrification program.

3. Methodology

3.1. Measurement using contingent valuation method

The economic benefits of improved electricity service connection can be measured using a contingent valuation (CV) approaches. Contingent valuation is a value elicitation survey method that enables systematically collect consumers' willingness to pay data for a proposed new policy, or program or service provision (Kwak et al., 2013). Since contingent valuation method uses hypothetical scenario to ask respondents about the subject of interest, opposing to observing their actual behaviour, this is become the source of both its strength and weakness of the CV method. However, a blue-ribbon National Oceanic and Atmospheric Administration (NOAA) argue that the CV method better produces an estimates with more reliable to be the starting point for administration and judicial determination (Arrow et al., 1993). The contingent valuation method can produce reliable and valid result if professional interviewers are employed and the respondents are familiar with the good and services to be valued.

3.2. Sampling and survey methods

Professional enumerators were hired to gather households' WTP for renewable sources of electricity service connection and its attributes by employing multistage sampling techniques. Initially the two woredas (districts) were purposively identified based up on the condition that both districts are ideal places for supply of both Grid electricity and Solar PV electricity services. On the second stage, one kebele (small district administrative unit in Ethiopia) from each woredas were purposively identified on the condition that both kebeles have equal accessibility to both sources of electricity service connection. That means, in the selected two kebeles there was relatively better diffusion of solar PV system besides having grid electricity transmission line passing through them. However, the two selected kebeles have different agro ecological zones and way of livelihood representing different group of society. On the third stage using a systematic random sampling techniques the respondents were selected, based on sampling frame list obtained from the respective kebele administration office. The survey, administered to heads of households or house wives because of the fact that he or she is in charge of a family and pays utility bills. Moreover, face-to-face interview was chosen as a technique for eliciting data. According to Kwak et al. (2007), face-to-face interview is the preferred technique to telephonic interviews or e-mail, because it provides the greatest scope for detailed questions and answers. Description of the sample size from each kebele is summarized as Table 1 below.
entertainment and income generating purposes. However, the connection that can be used for lighting, charging mobile phone, cooking, and for different purposes. However, there are also homes like yours with no electricity services and used for cooking, lighting, mobile charging, TV and other purposes. However, there are also homes like yours with no having electricity connection and in its place uses fuels, charcoal for cooking, heating, and candles and paraffin for lighting purposes. The later options are expensive and inconvenient when used, not healthy and environmentally unfriendly. In order to overcome the later choices’ challenge and improve your current electricity problem, we are going to ask the value you put in place on two hypothetical sources of electricity (PV) products. The two renewable electricity products have their own attributes, and for each sources of electricity, two different payment mechanisms are proposed (lump sum based vs monthly based) for both products i.e. grid-electricity (GE) and solar (PV) electricity, on a monthly installment payment scheme, are $4.65, $ 9.3, $13.95 and $18.6 until the connection cost of electricity to their home is paid back. Another payment mechanism is a lump sum payment and the initial bids for both products are $46.5, $93, $139.5, and $186. These initial bid prices are randomly assigned to each respondent. A pre-test for the specified bid amount and pilot study was performed by the researcher before using the questionnaire for the survey.

### 3.3. Survey development

From the very beginning, the survey instrument was developed together with the help of an expert. After finalizing the questionnaire, we conducted a pre-test using a small focus group discussion (ten household heads from each kebele and a total of twenty household heads) in order to further improve the instrument based on their reaction before the main survey. On this pre-testing survey, we have also conducted the focus group discussion (FGD) in order to determine the initial bids in March 2016. Based on the result of FGD four different starting bids for both products and payment vehicle were determined. The initial bid price proposed for both products i.e. grid-electricity (GE) and solar (PV) electricity, on a monthly installment payment scheme, are $4.65, $ 9.3, $13.95 and $18.6 until the connection cost of electricity to their home is paid back. Another payment mechanism is a lump sum payment and the initial bids for both products are $46.5, $93, $139.5, and $186. These initial bid prices are randomly assigned to each respondent. A pre-test for the specified bid amount and pilot study was performed by the researcher before using the questionnaire for the survey.

### 3.4. Survey structure

In designing a contingent valuation survey, the proposed scenario should explain about the characteristics of the goods and services to be valued in order to be more clear and understandable, and enhance the credibility of the survey and produce reliable data. The questionnaire format consists of (i) introductory questions on electricity service provision; (ii) WTP questions on the renewable sources of electricity service connection; and (iii) questionnaire seeking respondents' information including different socio economic and demographic characteristics. The second part includes hypothetical scenario part that describes the good, which is being valued, as described above:

**The CV scenario;** suppose that there are homes that are connected to electricity services and used for cooking, lighting, mobile charging, TV and other purposes. However, there are also homes like yours with no having electricity connection and in its place uses fuels, charcoal for cooking, heating, and candles and paraffin for lighting purposes. The later options are expensive and inconvenient when used, not healthy and environmentally unfriendly. In order to overcome the later choices’ challenge and improve your current electricity problem, we are going to ask the value you put in place on two hypothetical sources of electricity connection. They are Grid line electricity (GE) and a photovoltaic solar electricity (PV) sources. The two renewable electricity products have their own attributes, and for each sources of electricity, two different payment mechanisms are proposed (lump sum based vs monthly based) which is described one by one as follows:

#### Scenario 1. Grid line Electricity with lump sum payment scheme

Suppose the grid electricity service (GE) is reliable (no blackout in 24 h) that can be used for lighting, charging mobile phone, cooking, and for different entertainment and income generating purposes. However, the connection payment for this GE is a fixed lump sum payment of birr 5000 ($ 233)

- **Scenario 2. Grid line Electricity with monthly-based payment scheme**

  Suppose now you are allowed to pay the initial connection fee of birr 5000 ($ 233) based on monthly based installment for the duration of 5 years (60 months), excluding the usage fee. However, you will be connected to the services after three months consecutive payments. Therefore, now let me ask you some values to know how much you (as household head) are willing to pay for GE connection using a lump sum payment modality. Please consider your affordability, other necessity expenditure you need to prioritize and your preparedness when you reply to these WTP questioners.

**Willingness to pay questionnaires for Grid-Electricity service connection;**

1. Would you willing to pay a lump sum fee of birr [...] to be connected to the grid-electricity services I explained above?
2. If no, would you willing to pay a lump sum fee of birr [...] to be connected to the grid-electricity services I explained above?
   - [Additional] if (no, no); what is the minimum amount of birr you would like to pay?
3. If yes, would you willing to pay a lump sum fee of birr [...] to be connected to the grid-electricity services I explained above?
   - [Additional] if (yes, yes); what is the maximum amount of birr you would like to pay?

**Scenario 2. Grid line Electricity with monthly-based payment scheme**

Suppose now you are allowed to pay the initial connection fee of birr 5000 ($ 233) based on monthly based installment for the duration of 5 years (60 months), excluding the usage fee. However, you will be connected to the services after three months consecutive payments. Therefore, now let me ask you some values to know how much you (as household head) are willing to pay for GE connection using a lump sum payment modality. Please consider your affordability, other necessity expenditure you need to prioritize and your preparedness when you reply to these WTP questioners.

**Willingness to pay questionnaires for Grid-Electricity service connection;**

1. Would you willing to pay a lump sum fee of birr [...] to be connected to the grid-electricity services I explained above?
2. If no, would you willing to pay a lump sum fee of birr [...] to be connected to the grid-electricity services I explained above?
   - [Additional] if (no, no); what is the minimum amount of birr you would like to pay?
3. If yes, would you willing to pay a lump sum fee of birr [...] to be connected to the grid-electricity services I explained above?
   - [Additional] if (yes, yes); what is the maximum amount of birr you would like to pay?

7 The connection cost of electricity for houses within 1km radius from the Grid transmission line was estimated to be about $ 233 and the cost of Solar PV module and with all its set was also about $ 233 in 2012, by ErG Ethio Research Group (2012). The study adopts this cost as a reference.

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*1 Source: population census of 2007.

*2 See additional ‘Survey instrument, Questionnaires’ supplementary file.

*3 Exchange rate in 2016 was 21.5 ETB = $ 1. 

| Woreda (kebele) | Number of Households | Selected households | Percentage of sampled household from each district |
|-----------------|----------------------|---------------------|-----------------------------------------------|
| Boset (Xiiyyo)  | 1840                 | 127                 | 6.9                                            |
| Hexosa (Harbe)  | 1360                 | 93                  | 6.8                                            |
| Total           | 3200                 | 220                 | 6.9                                            |

Source: population census of 2007.
Scenario 3. Solar electricity (PV) with a lump sum based payment scheme

Suppose that the Ethiopia electric power corporation (EEPCO) want to distribute the solar home system (PV) appliances set to a household who want to connect to it. The maximum solar PV to be distributed by EEPCO shall include 40 WP (watt peak), that helps you to use two light bulbs, one TV or to connect to it. The cost of this solar machine is a fixed sum of 5000birr ($ 233) including its own storage battery and solar panels, but without including bulbs and home wiring. Once you installed it, no other costs except replacement of battery and bulbs when broken or run out. You will get uninterrupted power supply as long as solar panel and batteries work properly and its maintenance is just as easy as cleaning the solar panels. Once you paid a lump sum payment, the solar machines will automatically installed on you home. Therefore, now let me ask you some values to know how much you (as household head) are willing to pay for solar electricity connection based on lump sum payment. Please consider your affordability, other necessity expenditure you need to prioritize and your preparedness when you reply to these WTP questions.

Willingness to pay questionnaires for solar electricity;

7. Would you willing to pay a lump sum fee of birr [...] to be connected to the solar-electricity services I explained above?
8. If no, would you willing to pay a lump sum fee of birr [...] to be connected to the solar-electricity services I explained above?

9. If yes, would you willing to pay a lump sum fee of birr [...] to be connected to the solar-electricity services I explained above?

Scenario 4. Solar electricity (PV) with a monthly-based payment scheme

Suppose you are allowed to be connected to a solar PV system by paying fixed monthly installment based for the duration of five years (60 months). The total cost of solar PV is same as already described above birr 5000 ($ 233) including its own storage battery and solar panels, but without including bulbs and home wiring. However, you need to pay three months consecutive payments in advance in order to get solar electricity installed to your home. Therefore, now let me ask you some values to know how much you (as household head) are willing to pay for solar electricity service connection by monthly installment modality. Please consider your affordability, other necessity expenditure you need to prioritize and your preparedness when you reply to these WTP questioners.

Willingness to pay questionnaires for solar electricity;

10. For the coming 60 months, are you willing to pay birr [...] every months to be connected to solar-electricity services I explained above?
11. If no, for the coming 60 months, are you willing to pay birr [...] every months to be connected to solar electricity services I explained above?

12. If yes, for the coming 60 months, are you willing to pay birr [...] every months to be connected to solar electricity services I explained above?

3.6. Model specification

3.6.1. Empirical model

Inquiring the respondents’ WTP directly is the usual method in most CVM studies, but inquiring the payment amount, i.e. open-ended method, is not suggested. The later will often get the results of missing values for respondents find it difficult to answer. This study focuses on the closed-bounded method to elicit the WTP that is to ask the respondents’ willingness to pay under a given amount. The close-bounded method can be applied and divided into single-bound, double-bound or multiple bound depends on the number of times to question. This study uses the double-bounded format by a following up questionnaire for the purpose of statistical efficiency (Hanemann et al., 1991; Cameron and Quiggin, 1994; Alberini, 1995; Liu and Chen, 1996). Based on its empirical evidences and theoretical superiority in efficiency gain, the study adopts the double bounded dichotomous choice format. Let $I_1$ be the first bid price and $I_2$ be the second bid price. Then the WTP can be bounded in: $I_1 < WTP < I_2$ for the yes-no responses; $I_2 < WTP < I_1$ for the no-yes response; $WTP > I_1$ for the yes-yes response; and $WTP < I_2$ for the no-no response. Using econometrics model the double bounded willingness to pay data can be modelled using a logarithm function of its explanatory factors as per (Fu et al., 1999)

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Footnote:
8 Hypothetical bias is a case where respondents either not pay or less pay when compared to the real life situation.
\[
\log(WTP_i) = X_i\beta + \mu_i
\]  

Where \(WTP_i\) represents the \(j\)th respondents WTP, and \(i = 1, 2\) represents the first and the second answers, \(X_i\) is the vector of the other observable attributes of the individual which might affect one's willingness to pay; \(\mu_i\) is error terms which follows and assumes \(\mu_i \sim N(0, \sigma^2)\). Depending on the arguments with related to the assumption for the average values of error terms with related to the individual covariates, it is possible to use; the bivariate probit model as proposed by Cameron and Quiggin (1994), the random effects probit model (Alberini et al., 1997) and the interval-data logit model (Hanemann et al., 1991). According to Alberini (1995), estimates of bivariate probit model is preferred to that of interval data logit, when the correlation coefficient between the two consecutive bid error terms is close to zero. Therefore, after checking the correlation coefficient for the first and subsequent responses, the study used bivariate probit model. \(^9\)

In using contingent valuation approach, the bid function model is described, where binary choices data from the bids are used to estimate the willingness to pay values. The second question involves the acceptance of another birr amount depending on the first answer. The study assumes the unobserved willingness to pay of the respondent \(i\) \(WTP_i\) in first question is between the lowest value \((WTP_i^0)\) and the highest value \((WTP_i^1)\). Therefore, we might have four types that result from the following up question by respondents' reply "yes" or "no". (1) YES-YES means "yes" for the bid price in first and second question, and the highest WTP in the mind of respondents will be between \(WTP_i^0\) and \(WTP_i^1\); (2) YES-NO presents "yes" for the first bid price but "no" for the second price, thus the highest WTP is between \(WTP_i^0\) and \(WTP_i^2\); (3) NO-YES means "no" for the first bid price but "yes" for the second price, and the highest WTP is between \(WTP_i^2\) and \(WTP_i^1\); (4) NO-NO means "no" for both of the two questions and the highest WTP will be between 0 and \(WTP_i^2\). According to Lin et al. (2013) the four types can be expressed by the following equations,

\[
(I_1, I_2) = \begin{cases} 
(1, 1), & \text{if } X_i\beta \geq \log(WTP_i^1) \\
(1, 0), & \text{if } X_i\beta \geq \log(WTP_i^0) \text{ and } X_i\beta < \log(WTP_i^1) \\
(0, 1), & \text{if } X_i\beta < \log(WTP_i^0) \text{ and } X_i\beta \geq \log(WTP_i^2) \\
(0, 0), & \text{if } X_i\beta < \log(WTP_i^0) 
\end{cases}
\]  

Where, \(I_1^1\) and \(I_2^1\) represent the decision of the first and second question, respectively. If the respondents answering is YES then \(I_1 = 1\), inversely NO for \(I_1 = 0\). We can get the four results of \((1,1), (1,0), (0,1)\) and \((0,0)\) means to (YES,YES), (YES, NO), (NO,YES) and (NO,NO) in respectively. For econometric investigation, a household’s response is modelled using a probability function which a respondents can select one outcome among these mutually exclusive options. The probabilities are calculated as follows:

\[
P(I_1^1 = 1, I_2^1 = 1) = 1 - \Phi\left(\frac{\log(WTP_i^0) - X_i\beta}{\sigma}\right) 
\]

\[
P(I_1^1 = 1, I_2^1 = 0) = \Phi\left(\frac{\log(WTP_i^0) - X_i\beta}{\sigma}\right) - \Phi\left(\frac{\log(WTP_i^1) - X_i\beta}{\sigma}\right) 
\]

\[
P(I_1^1 = 0, I_2^1 = 1) = \Phi\left(\frac{\log(WTP_i^0) - X_i\beta}{\sigma}\right) - \Phi\left(\frac{\log(WTP_i^2) - X_i\beta}{\sigma}\right) 
\]

\[
P(I_1^1 = 0, I_2^1 = 0) = \Phi\left(\frac{\log(WTP_i^0) - X_i\beta}{\sigma}\right) 
\]

The parameters in Eqs. (3), (4), (5), and (6) are estimated by Maximum log-likelihood function because of its asymptotically efficient estimator for a set of parameters (Greene, 2003). Then accordingly, the log-likelihood function is sated as Eq. (7).

\[
\ln L = \sum_{i=1}^{n} I_1^1 I_2^1 \ln \left[1 - \Phi\left(\frac{\log(WTP_i^0) - X_i\beta}{\sigma}\right)\right] + I_1^1 (1 - I_2^1) \ln \left[\Phi\left(\frac{\log(WTP_i^0) - X_i\beta}{\sigma}\right) - \Phi\left(\frac{\log(WTP_i^1) - X_i\beta}{\sigma}\right)\right] 
\]

\[
+ I_2^1 (1 - I_1^1) \ln \left[\Phi\left(\frac{\log(WTP_i^0) - X_i\beta}{\sigma}\right) - \Phi\left(\frac{\log(WTP_i^2) - X_i\beta}{\sigma}\right)\right] + (1 - I_1^1)(1 - I_2^1) \ln \left[\Phi\left(\frac{\log(WTP_i^0) - X_i\beta}{\sigma}\right)\right] 
\]

Where \(\Phi(\cdot)\) is the standard normal cumulative distribution function, \(\sigma\) is the standard deviation of \(X_i\beta\).

3.7 Variables in the model

Households’ Willingness to pay (HWTP) binary choices for renewable source of electricity service connection is the dependent variable of the model in this study. It is assumed that WTP is determined and explained by different socio economic and demographic characteristics. In the context of this study, the value that household places to get electricity

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\(^9\) To estimate bivariate probit model the mean of initial question \(\mu_1\) and the second follow up questions \(\mu_2\) are assumed independent and the covariance are assumed zero.

\(^{10}\) Socio-economic and Demographic variables.
services is indirectly measured by the amount they are willing to pay (WTP) for it. The bids and socio economic and demographic variables are considered as the independent variables. The summary of variables and its description is as shown below in Table 2.

With regard to the households’ income variables, the study used the gross estimated farm revenue as a proxy for household income. It constitutes income from crop production, animal and animal products and income from other services. Of the above variables, few variables are just explained under descriptive statistics and others are used for econometrics estimation purposes as well.

4. Result and discussion

4.1. Descriptive analysis

Out of 220 respondents 205 (93%) are male and 15 (7%) are female headed households. This is so because by default husband is the household head in Ethiopia unless the husband divorced or widowed. The type of household houses in the rural areas matter to be connected to electricity service and hence about 35.5 percent of the respondents’ house is made of iron sheet roof and about 64.5 percent is made of grass roof. With regard to household occupation the majority of them, about 95.9 percent were agrarians. Besides this, most of the respondents have an interest to create business if electricity is provided to them. According to the survey result out of 220 respondents, 212 (96 percent) household have an interest to create their own business and the remaining 8 (4 percent) have no interest to create a business whether they are connected to electricity or not. When we consider the family size of the households, the average number of family size is six in a given particular household, which is greater than the average family size of the zone/and region that is 4.58 per household.

The average estimated household income from the survey is 16451.96 birr ($ 765) with a minimum of 1002 birr ($ 46.6) and a maximum of 123,165 birr ($ 5728) per year. The aggregate income is calculated by summing up income from different sources, as per the questionnaire design. The average age of respondents, (household head) is 40.55 years with a minimum of 20 and maximum of 85 years.

With regard to education variable, the average schooling for the sampled household head is 3.3 years. Using categorical forms Table 3 summarizes the education level of respondents as shown below.

Table 3 indicates that over 50 % of the respondents have completed eight years of primary education and 9.1% have attained secondary schooling. Moreover, one respondent had attained a tertiary education. Of the total sample size, 40.45% of the respondents have no formal education at all. In general here below, Table 4, is the summary of descriptive statistics for each variables considered in this study.

4.2. The dichotomous response

The distribution of the double-bounded dichotomous choice response is in line with the law of demand theory. That means, the percentage of NO–NO response increases with the initial bid price that the respondents faced. This distribution is just what is expected. The higher the price is; the lower acceptance by the respondent for both payment vehicles. The detail is shown in Table 5 below:

As Table 5 shows the percentages of NO–NO increases as the initial bid price increases for both electricity goods. Inversely the percentages of YES-YES decreases as initial bid price increases. The same is true for monthly instalment based payments of electricity service connection, which is summarized below in Table 6:

In addition to explaining the distribution of dichotomous response to different electricity goods across different payment modalities, it would

| Categories of variables | Variable name | Number of observation | Definition of the variables |
|-------------------------|---------------|-----------------------|-----------------------------|
| Joint dependent variable| WTP1          | 220 x 4 initial bids  | Yes or No response for the willingness to pay questions using the first initial bids |
|                         | WTP2          | 220 x 4 follow up bids| Yes or No response for the willingness to pay questions using the follow up bids |
| Independent variables   | BID PRICE     | 220 x 8 BIDS          | The initial bid price level households are asked whether they can pay or not. Monthly bids are (US $): 4.65, 9.3, 13.95, and 18.6 |
|                         | HH INCOME     | 220                   | Aggregated household income level from different sources |
|                         | AGEHH         | 220                   | Age of the household head (respondents) by survey time in years |
|                         | YEARS EDUC    | 220                   | The maximum years of schooling attended of the household head |
|                         | MARITAL STATUS| 220                   | Dummy coded 1 if selected household is married, 0 otherwise |
|                         | FAMSIZE       | 220                   | The number of family member in that particular household during survey time |
|                         | TYPE HOUSE    | 220                   | Dummy coded 1 if the household member is living/have house made of corrugated iron sheet, 0 otherwise |
|                         | LOCATION      | 220                   | Dummy coded 1 if the household is located in Hixon (Harbe), 0 otherwise |
|                         | SEXHH         | 220                   | Dummy coded 1 if the household head is male, 0 otherwise |
|                         | INTERESTBUS   | 220                   | Dummy coded 1 if the particular household has an interest in running business after electricity connection, 0 otherwise |
|                         | PROFESSION    | 220                   | Dummy coded 1 if the household is fully engaged in farming (both crop and livestock), 0 otherwise |

Table 2. Description of the variables.

Table 3. Education levels of household heads in percentage.

| Number of respondents | Percentage |
|-----------------------|------------|
| Have no any formal education | 89 | 40.45 |
| Attained primary level (0-8) years | 110 | 50 |
| Attained secondary level (9-12) years | 20 | 9.1 |
| Attained tertiary level (>12) years | 1 | 0.45 |

Source: survey result, 2016
be informative to summarize the overall trends of number of YES-NO response across consecutive bids as below Table 7.

As observed in Table 7 above, the number of responses NO–NO for the willingness to pay across initial bid and follow up bids declines whereas the number of response YES-YES for the willingness to pay across initial bid and follow up bid increases respectively in all modalities.

It is also noteworthy that protest responses are also censored and removed in this study. Protest response samples are those respondents who refused to pay for electricity connection, and those who do not value electricity service connection for different reasons and hence should be treated carefully (Frey and Pirscher, 2019). According to a questionnaire in the survey that addresses respondents’ reason for unwilling to pay, about 39 respondents are considered as protest (may be satisfied with the existing status quo) and about 21 respondents were with zero WTP response. Of the 39 respondents, 77 percent did not need to be connected to PV (solar electricity) for unknown reason and 15.4 percent did not need to be connected to grid electricity for similar reason.

### 4.3. Econometric analysis

This study uses bivariate probit model to estimate the willingness to pay based on the consideration of error correlation between the responses for the first bid question and the second follow up bid question. Accordingly, the study best fits with the bivariate probit model since the correlation between the two dependent discrete variables (1st bid WTP response and 2nd bid WTP response) are 0.765, -0.999, -0.629, and -0.468 for Lump sum GE, monthly GE, lump sum PV, and monthly PV models respectively and are statistically significant at 5% significance level. This indicates that a separate probit model is not a good option for the estimation (Nieto and Santamaría, 2010). Furthermore, the interval data logit model does not fit because of the result of the correlation between the two dependent variables that indirectly captures that of the respective error terms as shown by the ‘rho’ in the bivariate probit estimation result.

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**Table 4.** Descriptive statistics of socioeconomic and demographic characteristics of households.

| SED | Mean in birr (ETB) | Std. Dev. | Minimum | Maximum | Expected sign |
|-----|-------------------|-----------|---------|---------|--------------|
| BID, LUMPSUM, GE | 2386.67 | 1133.89 | 1000 | 4000 | -ve |
| BID, MONTHLY, GE | 238.67 | 113.38 | 100 | 400 | -ve |
| BID, LUMPSUM, PV | 2413.33 | 1136.26 | 1000 | 4000 | -ve |
| BID, MONTHLY, PV | 238.67 | 113.38 | 100 | 400 | -ve |
| HINCOME | 16451.96 | 15210.71 | 1002 | 123165 | +ve |
| AGE, HH | 40.54 | 12.50 | 20 | 85 | -ve |
| SEX, HH | .96 | .197 | 0 | 1 | |
| YEARS, EDUC | 3.28 | 3.47 | 0 | 13 | +ve |
| FAM SIZE | 6.03 | 2.66 | 0 | 14 | |
| MARRY STAT | .95 | .23 | 0 | 1 | |
| TYPE WORK | .92 | .25 | 0 | 1 | |
| INTERST BUSINESS | .97 | .18 | 0 | 1 | +ve |
| TYPE HOUSE | .4 | .49 | 0 | 1 | |
| LOCATION | .46 | .50 | 0 | 1 | |

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**Table 5.** The distribution of dichotomous responses for lump sum payments of both products.

| Type of product | Initial bid | YES-YES | YES-NO | NO-YES | NO-NO | Obsa |
|----------------|-------------|---------|--------|--------|-------|------|
| GE             | 1000        | 33-33 (55%) | 33-27 | 27-33 | 27-27 (45%) | 60 |
|                | 2000        | 28-30 (50%) | 28-28 | 28-29 | 29-28 (50%) | 58 |
|                | 3000        | 22-29 (50%) | 22-22 | 29-22 | 29-22 (50%) | 51 |
|                | 4000        | 20-24 (44%) | 20-27 | 27-31 | 31-27 (56%) | 51 |
| PV             | 1000        | 25-28 (52%) | 25-23 | 26-28 | 26-23 (48%) | 51 |
|                | 2000        | 24-30 (45%) | 24-30 | 36-30 | 36-30 (55%) | 60 |
|                | 3000        | 24-27 (44%) | 24-31 | 34-27 | 34-31 (56%) | 58 |
|                | 4000        | 20-27 (44%) | 20-24 | 31-27 | 31-24 (56%) | 51 |

Obsa: shows number of observation corresponding to each initial bid. Source: survey result, 2016

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**Table 6.** Distribution of dichotomous responses for monthly payments of both products.

| Type of product | Initial bid | YES-YES | YES-NO | NO-YES | NO-NO | Obsb |
|----------------|-------------|---------|--------|--------|-------|------|
| GE             | 100         | 30-37 (56%) | 30-23 | 30-37 | 30-23 (44%) | 60 |
|                | 200         | 28-33 (53%) | 28-25 | 30-33 | 30-25 (47%) | 58 |
|                | 300         | 23-30 (52%) | 23-21 | 28-30 | 28-21 (48%) | 51 |
|                | 400         | 23-26 (48%) | 23-25 | 28-26 | 28-25 (52%) | 51 |
| PV             | 100         | 27-34 (51%) | 27-26 | 33-34 | 33-26 (49%) | 60 |
|                | 200         | 26-30 (50%) | 26-21 | 25-30 | 25-21 (50%) | 51 |
|                | 300         | 26-27 (46%) | 26-31 | 32-27 | 32-31 (54%) | 58 |
|                | 400         | 22-25 (46%) | 22-26 | 29-25 | 29-26 (54%) | 51 |

Obsb: shows number of observation corresponding to each initial bid. Source: survey result, 2016
Among the socio-economic and demographic variables used in the model, households' income, age of household head, level of education, initial bids and locations are found to be statistically significant in influencing willingness to pay for electricity service connection for all models. The result of the bivariate probit model is given below.

The test statistics to evaluate the validity and significance of the model parameters are the likelihood ratio or Wald test (for overall joint test). In all models, the coefficients were jointly significant at 10%, 5% and 1% significance levels (* denotes for 10%, ** denotes for 5% and *** denotes for 1% level of significance, as shown in Table 9) using the Wald test. The hypothesis that all coefficients are simultaneously equal to zero in the bivariate probit model was tested using chi-square statistics. The tabulated Wald chi-square statistics at 5% significance level for each model are given in Table 9, where the degrees of freedom equal to the number of attributes/coefficients to be estimated. In this case, eight is 15.507; leading to rejection of the null hypothesis. Furthermore, just using the probability of chi-square value reported in Table 9, we could reject the null hypothesis mentioned above. This indicates that the model is efficient for explaining the variation in willingness to pay for green electricity service connection.

### 4.4. Discussion and Interpretation

The study estimated four models attributed to product types and payment schemes for connection to electricity services. The models are; Grid electricity connection with lump sum payment, Grid electricity connection with monthly instalment based payment, Solar PV electricity connection with lump sum payment, and Solar PV electricity connection with monthly instalment based payment. In all models, the willingness to pay for electricity service connection is significantly influenced by variables such as estimated household income, age of household head, educational background of household head, location of the respondents and bid prices. As shown in Table 9, the marginal effect coefficient of estimated household income has positive sign and significant impact on households' willingness to pay for all types of electricity products and payments schemes at least at 10% significance level. The result is in line with the economic theory for normal good (in fact, electricity is a normal good) that implies respondents with higher income have more WTP for electricity service connection just from affordability perspectives, assuming other things are constant. Just to compare with other study finding, a study in Kenya by Abdullah and Jeanty (2011) confirms similar results with regard to the impact of households income on demand for electricity service connection. Another study by Lay et al. (2013) also explored the determinants of households' choices of lighting fuels in Kenya and confirms that household income has positive and significant impact of households' solar home system adoption. Study by Zarnikau (2003) also confirms that consumers' characteristics such as income level positively affect willingness to pay for utility investment for electricity efficiency measures in the USA. In contrary study by Ek (2005) confirms that consumers' attitudes towards wind power electricity generation decreases with income may be due to the perception towards wind power electricity in the case of Sweden. However, in this study income level matters for getting electricity service connection in the rural areas of Ethiopia, and hence residents of the area as well as any organization, which promotes rural electrification program, should be aware of this fact to plan accordingly.

On the other hand, the marginal effect coefficient of the bid prices has negative significant influences on the households' willingness to pay for electricity service connection in all models. This result is also in line with the economic theory particularly the law of demand, which implies that the higher the money amount the respondents were asked to pay, the less likely they would agree to pay for electricity service connection. This is because of the fact that if consumers do not afford they would not have willingness to pay for an expensive services compared to the cheaper one. This result coincides with the findings of Abdullah and Jeanty (2011) which states that bid price has negative and significant (at 5% significance level) influences on households demand for electricity services connection. Although the study by Abdullah and Jeanty (2011) was conducted in Kenya, similar result has been achieved in Ethiopian context as per the findings of the current study. It appears that the scenario across East Africa region is similar with regard to rural electrification status and hence, what has been studied in one country could possibly be applicable in other countries in the region.

Table 7. Number of Yes-No Response across the bid.

| Response across different model | Number of observation | Number of observation | Remark |
|---------------------------------|-----------------------|-----------------------|--------|
|                                 | Initial bid           | Follow up bid         |        |
| Model 1 WTPNO                   | 117                   | 104                   | ↓      |
| Model 1 WTPYES                  | 103                   | 116                   | ↑      |
| Model 2 WTPNO                   | 116                   | 94                    | ↓      |
| Model 2 WTPYES                  | 104                   | 126                   | ↑      |
| Model 3 WTPNO                   | 127                   | 108                   | ↓      |
| Model 3 WTPYES                  | 93                    | 112                   | ↑      |
| Model 4 WTPNO                   | 119                   | 104                   | ↓      |
| Model 4 WTPYES                  | 101                   | 116                   | ↑      |

WTPNO: no response for specific willingness to pay question, WTPYES: yes response for specific willingness to pay question.
both payment schemes at least at 10% significance level. This result may reveal that older people may have less willingness to accept a change from their status quo may be due to fear of change, or because they do not trust both the government and the provider. Because of this behaviour, the older the household head gets the lesser the willingness to pay for electricity service connection irrespective of payment type. For those who responded NO, NO for both 1st bid and follow up bids, reasons for protests is identified as can be seen in Table 8. Just to compare this result with other study finding, study by Ek (2005) finds that consumers’ attitudes towards wind power electricity generation decreases with age may be due to fear of changes. Study finding by Zamikou (2003) confirms that consumers’ characteristics such as age positively affect willingness to pay for utility investment for electricity efficiency measures in the USA.

The other insightful variable in this study is location of the households that are captured by using dummy variable where value 1 is assigned to those who live in Hexosa (Harbe), and 0 for those who live in Boset (Xiiyo) kebele. Although the study proposes these two districts based on their accessibility to Grid line transmission and availability of potential Solar PV services, the estimated result appears to be significantly different. The marginal effect coefficient of location shows negative and significant influences on households’ willingness to pay for both electricity service connections at least at 10% significance level. This implies that households who live in Hixosa (Harbe) district have less/no willingness to pay for renewable sources of electricity service connection compared to the Boset (Xiiyo) districts. This result may indirectly reveal that households in Hixosa (Harbe) district have the opportunity to get other cheap energy sources such as charcoal, wood, and biogas (because of more livestock availability), excluding kerosene and other gases, relative to households in Boset (Xiiyo) districts. This reveals that households who have accessibility to cheap energy sources may value renewable energy sources less compared to the counter parts, assuming other things are constant. Therefore, this interpretation may give a sense that until the perception of the entire rural household shifts towards valuing renewable energy sources regardless of the availability of cheap non-renewable and unfriendly energy sources, the depletion of renewable resources cannot be halted.

Another important variable in this study is the type of house respondents live in. The type of house is captured by dummy variable in

### Table 8. Reasons for unwilling to pay for electricity service connection.

| Reasons for no-no response | Number of respondents (frequency) | Percent (%) |
|----------------------------|-----------------------------------|-------------|
| Not need solar PV for unknown reason | 30 | 77 |
| Not need grid line electricity for unknown reason | 6 | 15.4 |
| Not need solar PV because it is not worth to them | 2 | 5.1 |
| Not need electricity in general because they think it is not given a priority | 1 | 2.5 |

Total | 39 | 100% |

Source: Survey result, 2016

### Table 9. Bivariate probit estimation.

| Grid line electricity (GE) connection | Solar PV electricity connection |
|--------------------------------------|--------------------------------|
| Model 1 | Model 2 | Model 3 | Model 4 |
| Lump sum GE | Monthly GE | Lump sum PV | Monthly PV |
| Marginal effects | Z-value | Marginal effects | Z-value | Marginal effects | Z-value | Marginal effects | Z-value |
| BIDPRICE | -0.0679** (0.0275) | -2.47 | -0.054*** (0.0104) | -5.17 | -0.0210** (0.0092) | -2.27 | -0.0343*** (0.0102) | -3.35 |
| HH INCOME | 0.0625* (0.0369) | 1.69 | 0.0435*** (0.0072) | 6.03 | 0.0114*** (0.0013) | 8.91 | 0.0076* (0.0040) | 1.91 |
| AGE HH | -0.0235** (0.0113) | -2.08 | -0.0273* (0.0145) | -1.89 | -0.0572** (0.0215) | -2.66 | -0.0220** (0.0108) | -2.03 |
| YEARS EDUC | 0.0830* (0.0371) | 2.24 | 0.0930*** (0.0138) | 2.39 | 0.0707*** (0.0335) | 2.11 | 0.0553*** (0.0265) | 2.01 |
| FAMSIZE | -0.0041 (0.0492) | -0.08 | -0.0077 (0.0577) | -0.01 | -0.0100 (0.0429) | -0.23 | -0.0306 (0.0494) | -0.62 |
| MARITAL STATUS | 0.3651*** (0.1800) | 2.03 | 0.6340*** (0.2770) | 2.29 | 0.2144 (0.1783) | 1.20 | 0.5419* (0.2814) | 1.93 |
| TYPE HOUSE | 0.5133*** (0.2251) | 2.28 | 0.4119* (0.2417) | 1.70 | 0.4229* (0.2182) | 1.94 | 0.4166* (0.2317) | 1.80 |
| LOCATION | -0.3920*** (0.1556) | -2.52 | -0.4545* (0.2736) | -1.66 | -0.5901*** (0.2319) | -2.55 | -0.3622* (0.2161) | -1.68 |
| CONSTANT | 0.8936*** (0.3782) | 2.36 | 0.3198*** (0.1544) | 2.07 | 0.4123 (0.2812) | 1.47 | 0.1104* (0.0622) | 1.77 |

| WTP2 | WTP1 |
|-------|-------|
| BIDPRICE | -0.0068*** (0.0018) | -3.74 | -0.0076*** (0.0016) | -4.70 | -0.0341** (0.0138) | -2.46 | -0.0281*** (0.0128) | -2.20 |
| HH INCOME | 0.0285*** (0.00074) | 2.58 | 0.0177*** (0.0080) | 2.22 | 0.0189** (0.0078) | 2.41 | 0.0236*** (0.0079) | 2.86 |
| AGE HH | -0.0412*** (0.0165) | -2.49 | -0.0439*** (0.0200) | -2.19 | -0.0222* (0.0123) | -1.80 | -0.0405*** (0.0131) | -3.09 |
| YEARS EDUC | 0.0459* (0.0176) | 2.60 | 0.0865*** (0.0406) | 2.13 | 0.0414* (0.0244) | 1.70 | 0.0421*** (0.0153) | 2.76 |
| FAMSIZE | 0.0720 (0.0726) | 0.99 | 0.0760 (0.0552) | 1.38 | 0.1001 (0.0641) | 1.56 | 0.0865 (0.0642) | 1.35 |
| MARITAL STATUS | 0.4005 (0.2617) | 1.53 | 0.4176 (0.2902) | 1.44 | 0.5056*** (0.1936) | 2.61 | 0.2603* (0.1344) | 1.94 |
| TYPE HOUSE | 0.0361* (0.0187) | 1.93 | 0.0476*** (0.0182) | 2.61 | 0.0489*** (0.0221) | 2.21 | 0.0270 (0.0198) | 1.36 |
| LOCATION | -0.0961** (0.0384) | -2.51 | -0.0325* (0.0178) | -1.83 | -0.0922*** (0.0356) | -2.59 | -0.0582* (0.0301) | -1.93 |
| CONSTANT | -0.4463 (0.3332) | -1.34 | -0.6670 (0.4655) | -1.43 | -0.5814 (0.4309) | -1.35 | -0.5698 (0.4430) | -1.29 |
| RHO | 0.7653*** (0.2134) | 3.59 | 0.9995*** (0.2343) | 4.27 | 0.6290*** (0.1996) | 3.15 | 0.4679*** (0.1342) | 3.49 |

Wald chi2(16) | Wald chi2(16) | Wald Test rho = 0, wald chi2(16) = 2310.2 for the 1st model. N=362

### Notes

- **p < 0.01
- *p < 0.05
- p < 0.10
- Robust standard errors are reported in parentheses.
such a way that value one is designated to house made of corrugated iron sheet, and zero for others. Accordingly, the result shows that households who have house made of corrugated iron sheet roof have more willingness to pay for electricity service connection compared to other households who have house made of other materials. This variable seems to be a proxy for household income, although they are different and their correlation is small in the rural areas of Ethiopian context. This is because households in rural areas mainly depend on their asset such as number of livestock they have and number of land size they possess. What is more important is that they build houses by selling their asset, instead of depending on monthly or yearly income.

The marital status variable captured by dummy variable assigning one for married family, zero for others, has positive influence on the households’ willingness to pay in models with some of the payment schemes. The impact of the influence is significant at least at 10% significance level as can be seen in Table 9. This shows that married families are more likely to have children and large family size thereby exhibiting more responsibility to possessing renewable source of electricity service connection compared to their counterparts. This responsibility initiates them to have more willingness to pay for electricity service connection.

The last variable considered in the estimation of the models is family size. The family size variable is used in a continuous data form and its influence is insignificant in influencing households’ willingness to pay for renewable sources of electricity service connection in all models. This is perhaps due to its dual effect, on one hand large family size reduces the per-capita income that leads to low affordability and initiatives to pay for electricity service connection and on the other hand, large family size leads to more income sources and more energy demands that leads to more willingness to pay for electricity service connection, which actually depends on the age and health status of each family size. However, other similar studies have been conducted in other countries, for example in Kenya, which show, that family size and age of respondents have positive and statistically significant influence on households’ energy demands at 5% significance level irrespective of payment and product type which is contrary to the results of this study. The differences in the result may be attributed to the difference in socio-economic and demographic characteristics of the two different countries’ population. On the contrary, the findings of Ito et al. (2009) revealed that household size and ages were significant and negatively affect their willingness to donate for green electricity program in Japan.

4.5. Total willingness to pay

One of the objectives of this study is to investigate whether the cost of electricity service connection is recoverable or not. In order to achieve this objective, we need to know the total WTP, mean WTP and median WTP for electricity services connection. By employing Krinsky and Robb (1986) procedure12, Ekstrand and Loomis (1998) the mean and median WTP for renewable sources of electricity service connection are estimated and summarized below in Table 10. The median willingness to pay for grid-electricity services using a one time (lump sum) payment scheme is 3240 birr ($150.7) and by monthly instalment is 65.86 birr ($3.06) until cost of connection is fully paid back. Moreover, the median willingness to pay for solar electricity (PV) service using lump sum payment scheme is 2923.24 birr ($135.9) and by monthly basis, it is 59.92 birr ($2.8). Results from this estimation shows that respondents are WTP more for grid line electricity than solar electricity irrespective of the payment modalities.

The mean and median willingness to pay for grid electricity connection is greater than that of photovoltaic electricity irrespective of the payment method. The total WTP considering the two districts of the survey area is calculated as multiplying the total number of non-electrified household by the estimated mean WTP excluding the protests (Table 11). The reason for using median to calculate total WTP is that mean willingness to pay is misleadingly high if few individuals report very high willingness to pay amounts. Since it is reasonable to assume that in large number of contingent valuation studies the distribution of willingness to pay may fail to be normal, hence using median can reduce effects of outliers and skewed data (Carson, 1991).

The total annual WTP for each renewable source of electricity service connections is different among the payment schemes. For instance, the total willingness to pay values for both grid line and solar electricity, by a lump sum payment modality, indicates both are less than the amount of monthly instalment based total annual WTP values for their respective electricity types. As it is indicated in the Table 11 above, the total willingness to pay using monthly instalment payment scheme for grid line and Solar PV electricity services are 12.65 million birr ($459,822.5) and 11.51 million birr ($418,350.5) respectively. However, using a lump sum payment scheme, the total willingness to pay for grid line and solar electricity is greater than that of photovoltaic electricity irrespective of the payment modalities.

11 Every single model has double number of observation used for estimation purposes because of the fact that we used DBDC formats. Therefore, out of total 220-sampled households, 39 were excluded during the model estimation due to response protests. Therefore, 181 respondents’ multiply by two equal 362 observation are used for each model estimation.

12 Wpsqar command computes mean and median WTP including confidence intervals for each estimates.
PV electricity service connections are 10.37 million birr ($377,018.2) and 9.35 million birr ($340,158.8) respectively. This result implies that there is a strong preference for a monthly installment based payment scheme that can be attributed to household income level and different consumption priorities. At the same time, households are more likely to value GE connection than solar (PV) because total WTP for GE is greater than that of PV irrespective of payment modality. This result could be because of the perceived Grid line electricity service attributes including the power and duration of the electricity services. However, for scattered population with low density, the PV electricity connection was not as such less valued. For instance, Jackson and Oliver (2000) has found that connecting to Solar PV is least cost and can be an option for fewer residents in the area. Just for comparison purpose, a study by Yoo and Kwak (2009) used contingent valuation method to evaluate a benefit of introducing new policy that increases the production of green electricity consumption. The results revealed that respondents value the new policy and increases the green electricity consumption from 0.2 percent to 7 percent in 2011.

To sum up, the estimated values of this study are useful in policy making when the government, donors, and investors need to know the potential WTP for these renewable sources of electricity service connections in the rural households at these districts (kebeles) level using different payment scheme.

5. Conclusion and policy implications

5.1. Conclusion

Estimating the value of renewable source of electricity service connection in the rural household of Ethiopia by considering different products and payments options is of paramount significance for an optimal investment decision by both households and institutions involved in rural electrification program. Using a hypothetical scenario with double bounded dichotomous contingent valuation formats, the value of electricity service connection was estimated for the Bozet (Xiiyo) and Hexosa (Harbe) kebeles of rural households. Grid-line electricity and photovoltaics solar electricity services were considered as alternative source by households with lump sum versus monthly installment based payment mechanisms.

The result of the empirical model indicates that the rural households' willingness to pay alone is not sufficient to recover the cost of electricity connection. According to the ErG Ethio research Group (2012) the average cost of grid line electricity service connection for household within 1 km radius of grid line transformation is estimated to be approximately around 5000 birr ($223). For solar PV of 40 PW, it is almost about 5000 birr ($223). By using this cost index as a benchmark, the average household WTP for electricity service connection is not sufficient within the proposed 5 years maturity period (in the case of monthly installment basis). The variables such as household income, age of household head, years of schooling, location and bids (price) are the main significant factors determining households' willingness to pay for the renewable source of electricity service connection at least at 10% significance level irrespective of the type of electricity source and scheme of payments. In addition, the willingness to pay estimates for Grid line electricity service is found to be higher than that of solar PV electricity systems that may be put down to the attributes of grid electricity service, in particular power and duration of the service. The payment vehicle for electricity service connection plays significant role for accessing electricity to all income categories of rural households.

5.2. Policy implication

Understanding households' demands behaviour and WTP is crucial for welfare measures as well different stakeholders who want to invest in the sector. The total annual WTP value for both gridline and solar electricity for onetime payment indicates that both are less than their monthly total annual WTP values. Moreover, using a monthly installment based payment modality, for grid line and solar system the total payments, considering a 5 years maturity period, are 12.65 million birr ($459,822.5) and 11.51 million birr ($418,350.5) respectively. Using a lump sum payment modality, the total payment for both grid line and solar PV electricity service connection are 10.37 million birr ($377,018.2) and 9.35 million birr ($340,158.8) respectively. These values are deemed necessary for policy formulation when the government, donors, and investors need to estimate electrification services to rural households at the kebele level using various payment options. The following policy suggestions are proposed to boost connection for the non-electrified rural areas in Ethiopia although its cost may be high.

The electricity service providers need to consider rural households' willingness, abilities and suitability of payment modalities for the initial connection cost. This is because the payment modality is important factor for electricity connection to a household. As the findings of the study show, monthly installment based total WTP for electricity service connection is greater than a onetime payment for rural electrification services.

Another suggestion is adjusting a maturity period for post-paid electricity service connection by considering the households' affordability level. As it is proposed in the hypothetical scenarios of this study, a 5 years (60 months) pay-back period is not sufficient to recover the cost of connection, given the cost of connection is constant; i.e $233 (ErG Ethio Research Group, 2012). By considering the current household average WTP amount, it takes a period of seven to eight years to pay back the connection cost fully, even though it slightly varies from source to source. Therefore, any interested stakeholder should be aware of these facts before taking the initiative of providing electricity services to these rural communities.

If the maturity period is perceived to be too long, the other alternative shall be providing subsidy for the low-income households to help them connect to electricity services, since their WTP amount is less than the estimated cost of connection. For instance, countries such as Chile has an average state of subsidy, for rural electrification, per household about USD 1,510 (Jadresic, 2000), in Kenya, provinces that are perceived poorer were getting subsidy for rural electrification programme (REPs) than other provinces, which are better off.

Although the study gives insightful policy implications with regard to rural household preferences and electricity service connection in rural Ethiopia, it has some limitations. For instance, the study exclusively focused on two sources of renewable electricity services viz. hydro and solar in the rural areas of Ethiopia which were the only potentially feasible options at a time of the study; i.e. 2016. However, at this time and in the future, sources of electricity generation could be diversified based on the country's economic needs. Based on the consumers' source of electricity preferences and level of willingness to pay, the government and other electricity-supplying stakeholders will have proper and effective plan. Therefore, the researcher would like to suggest future research to consider all potential renewable electricity sources so as to have comprehensive households' preferences and draw comprehensive policy implications.

Regarding methodology, the researcher has exerted maximum effort to reduce some biases that could emanate from the nature of the study.
contingent valuation techniques during data collection. For example, the researcher has managed to reduce the starting point bias by conducting FGD and identifying four different starting points for each scheme prior to the study. This has reduced modality biases by introducing monthly based or lump sum based payment mechanisms. However, there could be minor strategic and information biases that could not be managed by the data collectors and the researcher.

Declarations

Author contribution statement

Birku Reta Entele: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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