Accepted Manuscript

Determinants of willingness-to-pay for attributes of power outage - An empirical discrete choice experiment addressing implications for fuel switching in developing countries

Kahsay Haile Zemo, Habtamu Tilahun Kassahun, Søren Bøye Olsen

PII: S0360-5442(19)30328-7

DOI: <https://doi.org/10.1016/j.energy.2019.02.129>

Reference: EGY 14771

To appear in: *Energy*

Received Date: 16 July 2018

Revised Date: 31 January 2019

Accepted Date: 17 February 2019

Please cite this article as: Zemo KH, Kassahun HT, Olsen SØBØ, Determinants of willingness-to-pay for attributes of power outage - An empirical discrete choice experiment addressing implications for fuel switching in developing countries, *Energy* (2019), doi: <https://doi.org/10.1016/j.energy.2019.02.129>.

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Determinants of Willingness-To-Pay for attributes of power outage - An empirical discrete choice experiment addressing implications for fuel switching in developing countries†

Kahsay Haile Zemo^{1*}, Habtamu Tilahun Kassahun² and Søren Bøye Olsen³

¹Department of Environmental Science, Aarhus University, Frederiksborgvej 399, 4000 Roskilde, Denmark.

²Australian Rivers Institute, Griffith University, Brisbane, Australia

³Department of Food and Resource Economics, University of Copenhagen, Denmark

*Corresponding author. E-mail: khz@envs.au.dk. †Declarations of interest: none.

Abstract

In many developing countries, there is a desire to switch from traditional fuel to renewable energy. However, the supply of renewable energy is often characterized by a severe lack of reliability. This paper seeks to answer if, and to what extent, power outages inhibit switching from fuelwood to hydropower based electricity supply, and factors that determine households' willingness to pay to reduce power outages using a unique combination of mixed logit and seemingly unrelated regression models. We find that frequency, duration, timing of power outages and advance notice are important characteristics determining whether households switch to electricity. The less reliable the electricity supply is the less likely households are to switch to it. Therefore, unreliability in electricity supply maintains the current use of fuelwood, resulting in continued environmental and health problems. Hence, policymakers should work to improve reliability to speed up the desired fuel switching process.

Key words: Fuel switching, power outage, reliability of electricity supply, developing country, discrete choice experiment, willingness-to-pay

1. Introduction

Although the switch to environmentally friendly electricity supplies such as solar wind or hydropower is advocated, and set up as one of the core targets of the sustainable development goals (SDG 7) [1], the switch to modern renewable energy from traditional fuels is quite slow in most developing countries [2]. Most of the existing electricity policies and practices are generally considered unsustainable [3]. For instance, the intensive use of traditional fuels¹ creates environmental (CO₂ emissions, deforestation, etc.) and health (local air pollution, indoor and outdoor) problems in many developing countries [5, 6].

Previous studies identified various household characteristics, fuel prices, access to fuels, and access and adoption of electric cooking appliances as the main limiting factors for households to switch away from fuelwood [e.g., 7, 8-10]. However, many of the previous studies have overlooked the importance of reliability of electricity supply on fuel switching. This is an important aspect particularly in Africa where power supply is characterized by frequent, long and erratic power outages [11-13].

Based on a data from 21 major cities in Sub-Saharan Africa, Gertler et al. [14] find that the electricity reliability rate is substantially lower than the access rate. Especially in countries like Ethiopia where almost entirely of the electricity supply is based on hydropower, the unreliability of the power supply remains a serious challenge. The power supply network and internal technical problems, inefficiency as well as some external man-made and natural problems are among the major sources of power outages [15]. The common causes of power outage can also be categorized as supply side factors, demand factors and political economy factors [for a

¹We use the term 'traditional fuels' mainly to refer to fuelwood (firewood, charcoal) and kerosene. The term 'modern renewable energy' refers to electricity that is generated from renewable energy such as hydropower, wind, solar and geothermal energy. In fact, Ethiopia generates nearly 100% of its electricity from renewable energy, mostly hydropower [4].

review, see; [14]. In such cases of unreliable electricity supply, it seems quite likely that households will be reluctant in switching fully to electricity.

In the literature, revealed and stated preference methods are used to assess preferences and values for the reliability of electricity services. For example, the production loss method and averting behavior approach have been used to value the cost of electricity interruption especially for business sectors [e.g., 16]. However, these methods are not easily applied to measure the welfare loss that households (residential customers) face from electricity interruption [16, 17]. In the domain of stated preference methods, a growing body of literature employs the contingent valuation method (CVM) and discrete choice experiments (DCE) in the valuation of the reliability of electricity service [e.g., 18, 19-24]. However, nearly all of these studies have been carried out in developed countries. A study by Abdullah and Mariel [18] is, to our knowledge, the only DCE study conducted in Sub-Saharan Africa. They conducted a DCE study to elicit households' willingness to pay for the improvement of electricity services in rural Kenya.

However, reliability of electricity may be more important in urban areas than rural areas due to the high population density in urban areas that results in lower reliability from overcrowding and opportunity costs of power outages are higher in urban areas since electricity is a critical input to many activities [14]. Thus, valuation of reliability of electricity services merits in-depth investigation in urban areas of developing countries to achieve greater insights on the impacts of unreliability of electricity services. To our knowledge, the current study is the first to link reliability of electricity supply from renewable energy sources with implications on fuel switching behavior using DCE in an urban area of a developing country. Hence, the important research question is if and to what extent power outages may inhibit the desired switch away from using fuelwood? Supplementary to this, it is relevant to investigate the relative importance

of different aspects of reliability such as duration, frequency and timing of power outages, as well as considering the possibility of making outages more acceptable by providing advance notice, which might enable households to prepare by planning and adjusting their power consumption. Another research question concerns how factors such as use and price of traditional fuels, income, and other household characteristics influence households' valuation of reliability of electricity service attributes.

To address the above research questions, we conduct a DCE, an increasingly popular stated preference approach. We collect data by conducting questionnaire based personal interviews with respondents living in urban households² in Ethiopia where traditional fuel is used for cooking by the majority of households. For the analysis of the choice data, we use mixed logit model (MXL) and seemingly unrelated regression model (SUR) is used for identifying the determinants of marginal willingness to pay (MWTP) for each attribute of power outage based on individual MWTP estimates retrieved from MXL model.

Our findings suggest that reliability of electricity may indeed be a major determinant for the desired fuel switching process. In addition, our results suggest that combining MXL and SUR models provides better information to the determinants of MWTP estimates for different aspects of power outage and we confirm that the SUR model outperforms the equation-by-equation OLS. Our results provide important input to policy makers aiming to speed up the process of fuel switching. Due to the rapid electrification in developing countries, the main focus of the current energy targets is promoting the use of electricity (from renewable energy) for cooking to reduce the local health and environmental problems from the use of traditional fuels. However, such

² Household refers to a person or a group of people who dwell together (under same roof) and is treated as an individual.

policies will be suboptimal if they do not take the reliability of electricity supply into consideration.

The paper is organized as follows: Section 2 presents the conceptual framework. Section 3 presents the design of CE, and survey administration. Section 4 present the modeling and estimation procedure. Section 5 presents the results and discussions, and finally Section 6 provides concluding remarks.

2. Theoretical Framework

Suppose that a household faces a range of fuel choices for cooking. For the sake of simplicity we assume that there are three categories of fuel types; traditional fuels (e.g., fuelwood) only, modern fuels only (electricity) and a combination of both traditional and modern fuels. Hence, a household can be labelled "non-switcher", "partial switcher" or "full switcher" depending on whether it chooses to use traditional fuels only, a combination of traditional and modern fuels or modern fuels only [25]. Following Dubin and McFadden [26], we describe the household's indirect utility function which represents the level of utility attained from a chosen fuel type at given prices and income.

Therefore, given three categories of fuel types, the conditional indirect utility function is:

$$U = U(E, P_T, P_M, I, S_E, \varepsilon_E, \eta) \quad (1)$$

where E is fuel type, P_T is price of traditional fuels, P_M is price of modern fuels, I is income of household, S_E is the observed attributes of the fuel type, ε_E is unobserved attributes of the fuel type and η is unobserved household characteristics.

We will now describe explicitly how reliability as an attribute of electricity may influence fuel choice and fuel switching. We hypothesize that reliability³ of electricity supply influences household's decision to switch away from the use of fuelwood. Hence, if the supply of electricity is unreliable then a household is likely to choose fuelwood or a combination of both fuelwood and electricity over electricity only. So, there are limits (tolerance levels) a household places on the unreliability of electricity that it can accept to keep using it. Suppose PO_n^* and PO_n^{**} are a household's tolerance levels, i.e. the maximum number of power outages that the household will accept if switching to using electricity only or a combination of electricity and fuelwood respectively. At PO_n^{**} the power outage situation is worse than at PO_n^* ($PO_n^* < PO_n^{**}$). Hence, if the current amount of power outages gets worse, the fuel switching process may reverse in the sense that a household is more likely to move away from electricity use towards traditional fuels. Opposed to that, if the reliability of electricity improves, then the fuel switching process can be maintained and the household is more likely to switch to electricity. The condition for the fuel switching process can be expressed as follows;

$$Fuel\ choice = \begin{cases} Electricity\ only\ if\ PO \leq PO_n^* \\ Combination\ of\ Fuelwood\ and\ Electricity\ if\ PO_n^* < PO \leq PO_n^{**} \\ Fuelwood\ only\ if\ PO_n^{**} < PO \end{cases} \quad (2)$$

where PO is the current level of power outage. The expression in equation 2 implies that the less reliable the electricity supply is, the slower the fuel switching process will be. Therefore, given that the electricity supply can have attributes that are related to power outage and other

³ By reliability, we refer to the interruptions of electricity supply that is explained in terms of the frequency of occurrence of power outage, length of power outage, timing of power outage and advance notice for planned power outage. However, we do not rule out the presence other reliability elements related to electricity, but we assume that missing aspects of reliability not covered here will be of only minor concern to households.

attributes that are not related to power outage, the indirect utility function can be further described as follows;

$$U = U(E, P_T, P_M, I, R_E, NR_E, \varepsilon_E, \eta) \quad (3)$$

where S_E has been decomposed into reliability related attributes, R_E which is expressed in terms of power outage, and non-reliability related attributes of the electricity, NR_E . The reliability attributes refer to the types of outages as well as prior notice of expected power outages. Thus, to understand how sensitive households are to these power outage related attributes and thereby to examine how power outages inhibit households from switching fully to electricity, the empirical DCE analysis concerns only non-switcher and partial switcher households.

3. Discrete Choice Experiment Approach and Survey Administration

3.1. Design of the Discrete Choice Experiment

The economic theory behind the DCE is Lancaster's characteristics theory of value. According to this theory, value to consumers is generated not by the goods in themselves, but by the multiple characteristics of the goods [27]. However, it is not always an easy task to describe goods and services entirely based on their attributes [28]. During the survey development phase of DCE, choice modelers should exert a considerable amount of time defining the relevant attributes and attribute levels of the good under consideration. Thus, designing and implementing a DCE survey requires close attention [28-31]. The following steps were taken to develop the survey used in this paper and to select the attributes of power outage in particular. First, an in-depth literature review was carried out to identify relevant attributes of power outage [e.g., 18, 21, 24, 32]. Second, the attributes and the questionnaire developed were tested and evaluated in a focus group interview conducted in Denmark. The six participants of the focus group discussion were

Ethiopian residents studying MSc and PhD programs at the University of Copenhagen, Denmark, and they had all been living in Ethiopia until recently. Third, another focus group interview was carried out in Mekelle city in Ethiopia with five electricity subscribers in the study area. Fourth, we conducted a pilot test. This involved testing the questionnaire developed based on the above three steps with 35 households in the study area. These steps are in line with the research design procedures suggested by Yin [33], as well as the guidelines for conducting stated preference surveys in developing countries [30, 31]. The attributes chosen to be part of the final survey were frequency of power outage, duration of power outage, timing of power outages, advance notice of power outage and method of notification for power outage. The attributes and levels are displayed in Table 1. To handle potential confusion with regard to percentage change in monthly electricity bill, which was used as payment vehicle, a conversion list example was provided.

Table 1. Definition and levels for electricity service attributes

Attribute	Definition	Levels	Coding
Frequency of power outage	The number of times electricity supply interruptions occur (per a month)	1, 3, 5, 6, 8,10	Continuous
Duration of power outage	The length of time that electricity is unavailable each time that it goes off (in hours)	1 , 2 , 3 , 4 , 5, 6	Continuous
Timing of power outage	The time of the days that electricity is unavailable	Weekdays after 6AM, weekdays after 10PM, and weekends	Dummy

Time for advance notice for the planned power outage	The time for prior notification that electricity will be unavailable.	Two weeks prior, One week prior, Three days prior, and One day prior	Dummy
Method of notification for planned power outage	The method by which announcement is made for electricity supply interruption before it occurs.	Text message (SMS), and Media. Media in this case refers to radio and television.	Dummy
Additional monthly electricity bill (%)	The extra monthly electricity bill a household pays.	+1 %, +5 %, +10 %, +20 %, +30 %, and +35%	Continuous

For the experimental design a D-efficient fractional factorial design was implemented assuming the MNL model using Ngene [34]. The design was constructed to produce 12 choice sets using priors from a pilot study of 35 respondents. Respondents were presented with three alternatives in each choice set with the third alternative always describing a status quo. Since power outages may not often occur at the same time in each part of the city, the current condition of power outage could be different among households. Hence, respondents were asked to state their current condition for each of the attributes.

In addition, respondents were provided information about all attributes, levels and their definitions before proceeding to the preference eliciting choice tasks. A warm up choice task was also presented to the respondents so as to reduce any instructional uncertainty associated with the choice tasks [35, 36]. The choice task example presents an opportunity for respondents to familiarize themselves with what might be perceived as unfamiliar and somewhat complex

choice situations. To minimize potential anchoring effects from the choice task example to the subsequent preference eliciting choice task, the example was framed as a transportation choice task, not in any way linked to the electricity supply attributes that were of particular interest to this study.

3.2. *Sampling and Survey Administration*

Before we proceed with the description of the survey methodology, we briefly discuss the characteristics of the Ethiopian electricity market. Currently, Ethiopia has around 4200 megawatts (MW) of installed electricity generation capacity, which is almost entirely based on hydropower. Only 25% of the population is connected to the national electricity grid. Furthermore, access to the national grid differs greatly across urban and rural areas. While the electrification rate in urban areas is around 85%, the equivalent number for rural areas is only around 10% [37]. The effective electricity tariff in Ethiopia is 0.032 USD per kwh which is one of the lowest in Africa [38]. The electricity generation, transmission, distribution and selling are mainly regulated by state and the Ethiopian power and electric power corporation (EEPCO) is the responsible enterprise. As of 2013, EEPCO has been structured into two public enterprises: Ethiopian electric power (EEP) and Ethiopian electric utility (EEU). EEP is responsible for generation, transmission of power and develop related infrastructure whereas EEU is responsible for distribution of electricity to customers throughout the country [39]. However, the government of Ethiopia has recently announced that it is considering to open the power sector to partial privatization [40].

Figure 1. Map of the study area

Respondents for the survey were sampled among urban residential electricity customers in the city of Mekelle in northern Ethiopia (fig. 1). The target respondents of this study were those who subscribed to electricity but still relied on traditional fuels for cooking i.e. households who either use traditional fuels only (non-switchers) or use a combination of traditional fuels and electricity (partial switchers) for their everyday cooking activities. In the study area, as of February 2014, there were around 30,000 residential electricity subscribers in the city [41]. Displayed in Table 2, a total of 210 respondents living in different housing environments⁴ were sampled from three electricity districts in Mekelle using a stratified random sampling technique. Of the 210 surveyed

⁴ In Ethiopia, houses are mainly of two types: Traditional and modern houses. Traditional houses are built of wood and mud, wood and thatch or reed and bamboo whereas modern houses are built of durable construction materials (e.g., bricks, cement) and sophisticated systems of construction. Many of the modern houses owned by households in the study area are single-storied buildings.

respondents⁵, 181 were active consumers of fuelwood for cooking. The survey questionnaire was administrated through personal interviews. For this purpose, experienced enumerators were hired and given additional training. The questionnaire content for the interview covered behavioral questions, current use of energy sources, the preference eliciting choice tasks, follow-up questions, attitudinal and socio-economic and demographics of households. The sampled respondents are representative of the electricity subscribers' in different districts of the city. However, we are unable to assess the representativeness of the sampled respondents in terms of distributions of socio-economic and demographic characteristics relative to the general urban population and electricity subscribers in Ethiopia due to lack of readily available recorded data on household heads. We are, however, able to compare the sampled respondents to the large-scale national demographic and health survey (DHS) dataset. DHS was compiled by the Ethiopian central statistical agency in 2016⁶ [42]. The sample statistics show that 61.8% are male-headed households, which is very close to the data reported by DHS (61.6%). In terms of literacy rate, 97.8% of men in the sample are literate compared to 92.5% in the DHS. The literacy rate for women in our sample (87.8%) appears to be somewhat higher than the literacy rate reported in DHS (77.9%). With respect to the household size, households with large family size are slightly overrepresented in our sample with an average household size of 4.7 compared to 3.8 reported in the DHS.

⁵ 13 respondents were dropped from the analysis since they were identified as protesters from follow up questions. The follow up questions were asked for respondents who always chose status quo. The specific statements that were classified as protests include: "the government should pay for the electricity service improvement", "the electricity authority should pay for the improvement", and "I need more information and time to answer the question". And 16 of the surveyed respondents were full switchers.

⁶ The DHS was conducted two years after our survey and hence, the comparisons should be made with this in mind.

Table 2. Active domestic electricity customers in Mekelle, Ethiopia in the three districts

Sub-district	Number of customers ^a	customers by percentage	Sampled customers
1	9537	32%	67
2	7455	25%	53
3	13026	43%	90
Total	30, 018	100%	210

^a Ethiopian Electric and Power Corporation Northern District [41]

4. Modeling Approach

4.1. Mixed logit Model

Assuming that an individual n faces a choice among J alternatives in each of the choice situations, the utility of an alternative j in choice situation t is described as sum of observed and unobserved components of utility [43], i.e.,

$$U_{njt} = \beta'_n X_{njt} + \varepsilon_{njt} \quad (4)$$

where; X_{njt} are the observed variables, β'_n is a vector of coefficients of the variables for respondent n representing the his/her tastes (i.e. random parameters), ε_{njt} is an unobserved random error term that is assumed to be Independently and Identically Distributed (IID). Further assuming that the error term follows an extreme value distribution enables modelling choices using a logit model formulation. We allow for preference heterogeneity by additionally assuming that preference parameters differ across respondents with a density of $f(\beta|\theta)$. Thus, the unconditional choice probability, P_{nit} , of respondent n choosing alternative i in choice task t is given by the MXL probability :

$$P_{nit} = \int \prod_{t=1}^T \left(\frac{e^{\beta' x_{nit}}}{\sum_j e^{\beta' x_{njt}}} \right) f(\beta) d\beta \quad (5)$$

The MXL model accommodates the estimation of individual specific preferences by deriving the individual's conditional distribution based on past choices, y . Using Bayes' rule the conditional distribution of β is denoted as:

$$h(\beta | y_n, x_n, \theta) = \frac{P(y_n | x_n, \beta) g(\beta | \theta)}{P(y_n | x_n, \theta)} \quad (6)$$

where $P(y_n | x_n, \beta)$ is the probability of respondent's choice given value of β , $g(\beta | \theta)$ is the density of β for the entire population, $P(y_n | x_n, \beta)$ is the probability of individual's choice and is the integral of the numerator. The mean of the parameter values is described as:

$$\bar{\beta} = \frac{\int \beta \cdot P(y_n | x_n, \beta) g(\beta | \theta) d\beta}{\int P(y_n | x_n, \theta) d\beta} \quad (7)$$

Since the integrals do not have a closed form, a simulated maximum likelihood procedure [43] is used to estimate the parameters of interest. For these simulations 500 halton draws were found to produce stable results using the NLOGIT econometrics software [44]. In the estimation, we assume a normal distribution for all parameters except for the price attribute. The price parameter is assumed fixed in order to avoid problems with non-existing moments when calculating the MWTP distribution in equation 8. The MWTP for any attribute is obtained by calculating the negative of the ratio of the partial derivatives of the indirect utility functions with respect to the attribute of interest and the price [45, 46]. Accordingly, the MWTP for some attribute of interest is given by:

$$MWTP = -\frac{\partial U_{nj}}{\partial X_{nj}^{NP}} \bigg/ \frac{\partial U_{nj}}{\partial X_{nj}^P} = -\frac{\beta^{NP}}{\beta^P} \quad (8)$$

where NP denotes the non-price attribute, P denotes the price attribute, and the betas are the parameters estimated in the model.

Describing utility in non-linear form of some of the attributes improves the fit of the model better than entering them linearly. For example, entering duration of power outage non-linearly significantly improves the fit of the data. Hence, the frequency and duration of power outages entered utility function non-linearly (in log-form). Following equation (8) the MWTP for these attributes is denoted as (for example for the frequency attribute):

$$MWTP = \frac{\beta^{freq} / freq}{\beta^P} \quad (9)$$

where β^{freq} and β^P are coefficients for the frequency and price attributes respectively, and $freq$ denotes the frequency of power outage per month.

4.2. *Seemingly Unrelated Regression (SUR) Model*

Once the individual MWTP is calculated for each attribute for each respondent based the conditional betas obtained in equation 7, the SUR model is utilized for estimating the determinants of the individual MWTP for the various attributes. The SUR model is a system of linear equations with errors that are correlated across equations for a given individual but not correlated across individuals. The main advantage of SUR model over equation-by-equation OLS is the gain in efficiency that results from the incorporation of correlation in unobservables across equations for a given individual [47]. Moreover, the model is well suited to identify the determinants of MWTP. Campbell [48] noted that accounting for the influence of household

characteristics through interaction with attributes or alternative specific constants does not give an appropriate means of identifying the determinants of WTP. Accordingly, individual n 's MWTP for attribute m is given by:

$$MWTP_{nm} = x'_{nm}\alpha_m + \varepsilon_{nm}, n = 1, 2, \dots, N, m = 1, 2, \dots, M \quad (10)$$

where x_{nm} are the explanatory variables comprising different household characteristics assumed to be exogenous, α_m are $K_m \times 1$ parameter vectors, ε_{nm} is an error term, N is the number of individuals, and M is the total number of equations in the SUR. In the estimation procedure, first all equations from $MWTP_{n1}$ to $MWTP_{nM}$ are stacked for a given individual:

$$\begin{bmatrix} MWTP_{n1} \\ \cdot \\ \cdot \\ MWTP_{nM} \end{bmatrix} = \begin{bmatrix} x'_{n1} & \cdot & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot \\ 0 & \cdot & \cdot & 0 \\ 0 & \cdot & 0 & x'_{nM} \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \cdot \\ \cdot \\ \alpha_M \end{bmatrix} + \begin{bmatrix} \varepsilon_{n1} \\ \cdot \\ \cdot \\ \varepsilon_{nM} \end{bmatrix} \quad (11)$$

Then, the model is estimated using feasible generalized least square estimator (FGLS).

$$\hat{\alpha}_{FGLS} = \left[\sum_{n=1}^N X'_n \Omega^{-1} X_n \right]^{-1} \sum_{n=1}^N X'_n \Omega^{-1} MWTP_n \quad (12)$$

where Ω is error variance matrix specified as:

$$\Omega = \frac{1}{N} \sum_{n=1}^N \varepsilon_n \varepsilon'_n \quad (13)$$

Socioeconomic and demographic characteristics of the respondents, fuel type and prices, appliances owned, and other explanatory variables are used for the SUR model estimation which is done in Stata 14 [49]. The description and summary statistics of these and other variables is presented in Table 3. The inclusion of the variables in the regression equation, however, is based on context and statistical relevance, which then may vary from equation to equation.

Table 3. Description and summary statistics of household characteristics

Variables	Description	Measurement	Summary statistics (mean)
Socioeconomic and demographic descriptors			
Income	Monthly income of Household (in log form)	Ethiopian Birr (ETB)	8.401
Age	Age of Household head's	Years	49.403
Household size	Total number of people who live in the household	Number	4.724
Type of fuel and its price used by the household			
Wood	Uses wood as main fuel for cooking	1 if yes, 0 otherwise	0.414
Electricity	Uses electricity as the main fuel for cooking	1 if yes, 0 otherwise	0.812
Wood expenditure	Monthly expenditure for wood	In ETB	67.486
Monthly bill	Monthly electricity bill	In ETB	116.457
Appliance ownership			
Refrigerator	Refrigerator ownership	1 if yes, 0 otherwise	0.707
TV	TV ownership	1 if yes, 0 otherwise	0.934
Mobile phone	Mobile phone ownership	1 if yes, 0 otherwise	0.95
Other variables			
Environmental pollution	How important do you think is environmental air pollution when you choose fuel for cooking	1 if very important, 0 otherwise	0.674
Sharing electricity	Electricity subscriber households' who share electricity to neighboring	1 if yes, 0 otherwise	0.42

	households		
Experience	Constrained to freely move/entertain outside home	1 if yes , 0 otherwise	0.403
Perception on traditional and modern fuels (agree=1, disagree=0)			
	Prices (bill) for modern fuels (electricity) are high as compared to expenditures on traditional fuels such as fuelwood		0.326
	Electricity is less reliable than traditional fuels		0.829
	Use of electricity has no or less negative effect on the environmental air pollution as compared to traditional fuels		0.956
	Use electricity reduces deforestation		0.983
	Use of electricity has no or less negative health impact compared to traditional fuels such as wood fuels		0.994
	Electricity is safe and sound to use compared to other fuel types such as fuelwood		0.762
	Price of electricity appliances is expensive compared to appliances for other fuels		0.602

5. Results and Discussion

5.1. Descriptive Statistics

Of the sampled households, almost 99% of respondents use charcoal for their day-to-day cooking activities and around 41% of the households use firewood for cooking. On the other hand, about 80% of the respondents in the sample are partial switchers⁷ meaning that they use electricity for cooking in addition to traditional fuels.

⁷The number should be interpreted with caution. The partial switcher households have not (yet) fully switched to electricity use for all their cooking activities. This is often the case when a household owns some cooking appliances that exclusively use electricity to operate. For example, a “mitad” is an electric cooking appliance (stove)

The sampled households' perceptions on use of traditional fuels and electricity for cooking are also reported in Table 3. The majority of the households (67.4%) disagree to the statement that the cost of electricity is expensive compared to expenditures on traditional fuels. However, around 83% of the households agree with the statement that electricity is less reliable than traditional fuels. This simple descriptive statistics seems to support our hypothesis that reliability of electricity inhibits fuel switching. Furthermore, the households are aware of the negative consequences of the use of traditional fuels. Almost all respondents agree to the statement that use of electricity (from renewable energy source) has no or little negative effect on environmental pollution and health compared traditional fuels and reduces deforestation.

5.2. *RPL and MWTP estimates for the attributes of power outage*

We estimate the RPL model with frequency and duration of power outage entered logarithmically, and timing of interruption, advance notice for planned interruption and notification method entered as dummy coded variables, Table 4. The log form provides an intuitively appealing concave and monotonically increasing relationship between cost and power outages [20, 23, 32, 50]. Intuitively, we expect the MWTP to avoid an additional power outage to be largest when power outages are rare, but as the frequency of power outage increases, the MWTP to avoid an additional outage decreases.

The results of the RPL estimation show that the attributes of power outage (frequency, duration and timing of power outage) and advance notice significantly influences choice of electricity service (Table 4). The frequency, duration and timing of power outage as expected have a negative effect on the choice of the electricity service, indicating that an electricity service

that is only used for baking injera (staple bread in Ethiopia). Of the sampled households, around 78% own a mitad but they all still use traditional fuels for their other everyday cooking activities.

is less likely to be chosen with an increase in the frequency of power outage, duration of power outage and if power outage occurs on weekends. The mean estimate for the frequency of power outage shows that frequency has a negative effect on the choice of electricity supply service indicating that it is less likely to be chosen if power outage occurs frequently. Similarly, respondents are less likely to choose an electricity supply service when power outage last for long. Besides, the parameter estimates also show significant preference heterogeneity, implying that respondents have different preferences for these attributes. Moreover, time and method of advance notice for planned power outage influence the choice of electricity service. Households generally prefer an electricity service with longer advance notice and this is shown by the significant and positive coefficients for two weeks and a week notice for a planned power outage. The results also confirm that, on average, SMS as a method of notification for a planned power outage is less preferred than media but again with significant preference heterogeneity among the respondents. Significant preference heterogeneity is also found for the timing of power outages. The negative estimate for the price attribute, described as the change in the monthly electricity bill, indicates that preferences for improved electricity service declines with higher payments – as it should according to economic theory.

The MWTP⁸ estimates and their standard deviations for the attributes of power outage are presented in Table 4. The MWTP estimates show that when households face power outages 10 times a month, on average households are willing to pay 1.857 ETB to reduce the frequency of outage by one per month. However, when households face power outages 3 times a month, the MWTP to reduce the frequency is 6.191 ETB per month. Hence, estimates for the frequency

⁸ The MWTP estimates in a monetary unit are computed multiplying the MWTP estimates in fraction by the average monthly electricity bill of sampled households' (116.5 ETB).

attribute show that household's MWTP varies with the levels and the result illustrates that the log-form of frequency of power outage yields a convex and a monotonically decreasing relationship between MWTP and frequency of power outage. The fact that it is convex means that households' MWTP resulting from a unit reduction in frequency of power outage is small when frequency of power outage that households' are actually facing is high than when they face less frequent power outage. Furthermore, the decreasing relationship between the MWTP estimate and the frequency of power outage implies that the higher the reduction of frequency of power outage, the more a household is willing to pay. Table 4 also produces a similar explanation for duration of power outage. It depicts that household's MWTP is lower for longer outages and it is higher for shorter outages.

Our results (MWTP reduces with the length of power outages) contrasts with Carlsson and Martinsson [21] who find that Swedish households' MWTP to reduce power outage increases with duration of power outages. The disparity between the results may be attributed to the nature of power outage in the countries of the studies and households' dependence on electricity use. The length of a power outage in developed countries is typically very short. For instance, the aggregated duration of power outages is on average around 140 minutes per year in Sweden. It is only for 27 minutes per year a customer experiences a power outage in the Netherlands [24]. Unlike households in developing countries, households in developed countries are highly dependent on electricity for their day-to-day household activity. This agrees with Ladenburg et al. [51] who find that Danish households' preference for the number and length of power outages does not change by provision of information on the positive influence of controlled power outage. Thus, it is not surprising to observe a positive relationship between MWTP and duration of power outages in developed countries.

Similar results are found in Abdullah and Mariel [18] indicating that households are willing to pay to reduce frequency and duration power outage. However, they assume a linear relationship between power outage and WTP, which is not intuitively sound assumption since previous studies have well documented that there is a monotonically increasing relationship between cost and power outage [e.g., 23, 32, 50].

Table 4. RPL and MWTP estimates for the attributes of power outage

Attribute	Level	Mean estimates	Std. dev	Level	MWTP Mean	MWTP std.dev
Log(frequency)		-1.108***	1.375***	10 times	-1.857***	2.304***
		(0.119)	(0.149)		(0.217)	(0.356)
				8 times	-2.322***	2.881***
					(0.271)	(0.446)
				6times	-3.095***	3.841***
					(0.361)	(0.595)
				5 times	-3.714***	4.61***
					(0.433)	(0.714)
				3 times	-6.191***	7.683***
					(0.722)	(1.191)
				1 time	-18.571***	23.048***
					(2.168)	(3.571)
Log(duration)		-0.665***	1.160***	6 hours	-1.859***	3.242***

		(0.123)	(0.109)		(0.353)	(0.464)
				5 hours	-2.231***	3.89***
					(0.423)	(0.556)
				4 hours	-2.789***	4.863***
					(0.529)	(0.696)
				3 hours	-3.719***	6.483***
					(0.706)	(0.927)
				2 hours	-5.578***	9.725***
					(1.058)	(1.391)
				1 hour	-11.155***	19.451***
					(2.117)	(2.781)
Timing	Weekday	-0.346	3.287***	Weekday	-5.797	55.108***
		(0.253)	(0.306)		(4.122)	(4.896)
	Weekend	-0.314*	2.079***	Weekend	-5.262*	34.847***
		(0.19)	(0.218)		(3.165)	(5.335)
Advance	Two	0.653***	0.769***	Two	10.943***	12.887***
notice	weeks	(0.157)	(0.258)	weeks	(2.795)	(4.612)
	One	0.363**	.719***	One week	6.084**	12.046***
	week	(0.173)	(0.263)		(3.028)	(4.571)
	Three	-0.384**	0.949***	Three	-6.434***	15.914***
	days	(0.166)	(0.179)	days	(2.762)	(2.883)
Notification		-0.422***	2.376***		-7.08**	39.835***

method	(0.156)	(0.257)	(2.758)	(4.18)
Bill	-6.949***			
	(0.524)			
ASC	-2.91***			
	(0.206)			
Log likelihood	-1492.218			
R-sq	0.375			
Adjusted R-sq	0.372			

Note: The standard errors are in parenthesis. ***, **, * indicate significance level at 1%, 5%, and 10%, respectively

The results of this study, the declining MWTP to reduce the frequency and duration of power outages, may have plausible economic and behavioral explanations, which may have interesting implications for fuel switching in developing countries. First, it seems reasonable that when power outages occur quite frequently and last long households are more likely to mitigate this by relying on other energy sources. Hence, households will resort to using multiple fuels for cooking to be less reliant on electricity. Fuel choice in developing countries, particularly in urban areas is typically relying on multiple fuels or fuel stacking for cooking and lighting [52, 53]. Secondly, when power outages occur very frequently households may substitute electricity once and for all with other traditional fuels such as fuelwood, kerosene and other fuels to avoid the negative impacts of power outages. Conversely, if households face less frequent and shorter power outages, they are more likely to rely on electricity as their main fuel for cooking. Thus, households are highly sensitive to any additional or more prolonged power outages and they have relatively high MWTP to reduce the frequency and duration of power outage. An alternative explanation is that according to prospect theory, the difference in the subjective value

between the gains of \$10 and \$20 is greater than the subjective difference between the gains of \$110 and \$120 [54], which then implies that reducing the frequency of power outages from 2 to 1 is more relevant to customers than reducing from 10 to 9.

The negative MWTP estimates found for frequency and duration seem reasonable considering the current situation in Africa in general and Ethiopia in particular where the majority of the urban population still relies on traditional fuels for cooking despite having access to electricity. Hence, the frequent and long power outages in many developing countries are most likely inhibiting households from switching fully to electricity as their main fuel, and it rather intensifies the use of traditional fuels thereby creating severe environmental and health problems.

The timing of power outages is also an important characteristic that influences the choice of electricity service. The estimates for the weekend power outage are significant and negative. This indicates that households' are less likely to choose an electricity service, which has power outages during weekends. The MWTP estimate in Table 4 underlines this, as households on average are willing to pay around 5.3ETB to avoid weekend power outages. This may be because households spend weekends (their leisure time) at home; they cook a lot, invite guests. However, there is a significantly large standard deviation in MWTP to avoid weekend power outages, which confirms huge variation in MWTP among households. Furthermore, it is possible to make power outages more acceptable by providing longer advance notice (such as two weeks and a week prior notice) for planned power outages. This also signifies that households are willing to pay more to get longer advance notice, e.g. two weeks or a week prior notice for a planned power outage. Specifically, households' are willing to pay on average around 10.9 and 6.1 ETB to get notification two weeks and a week prior, respectively. However, the mean parameter estimate for three days prior notice has significant and negative effect implying that

nearest notice of planned power outage is unacceptable by households'. The possible reason for this is that households need ample resources and time to prepare and adjust their consumption, and three days might not be seen as enough. Almost all of the households in our study area rely on fuelwood as mitigating measure for cooking when power outage occurs. However, households in urban areas cannot easily access additional fuelwood on short notice since it is transported from remote rural areas. Notwithstanding the significant preference heterogeneity reported in Table 4 it would seem that longer advance notice increases households' reliance on electricity, which is more likely to encourage them to fully switch to electricity use. Therefore, the policy makers should consider ensuring longer advance notice. The estimates in Table 4 illustrate that the method of notification is another important concern to the households, but it is one of the attributes with the highest standard deviations (39.835) signifying a great deal of preference heterogeneity to the extent that MWTP varies from -46.915 to 32.755 ETB among the respondents.

5.3. *Determinants of WTP for the attributes of power outage*

One of the reasons for investigating preference heterogeneity is that some households may be particularly reluctant to switch to electricity supply service. Socio-economic and demographic characteristics, characteristics of fuels and other factors may contribute to this. For example, fuelwood can be treated as an inferior good by high-income households but normal good by low-income households. Thus, high-income households unlike the low-income households may be willing to join to the proposed electricity improvement. Therefore, income could be a major source of heterogeneity, and thus, first we graphically investigate the variation in MWTP for the attributes explained by income. Then, the SUR model is utilized to account for income and other variables that explain the variation in MWTP.

Figure 2 shows the variation of MWTP for the attributes of power outages of the low and high-income households (based on median income of sampled households). Low-income households' MWTPs for the attributes of power outage are generally lower than the high-income households' MWTPs except for advance notice attributes (two weeks and three days prior notice). Low-income households have lower MWTP and higher variation of the MWTP to reduce frequency and duration of power outages and to get advance notice through SMS than high-income households. On the other hand, low-income households place higher value on longer notice (two weeks prior notice) indicating that they want to buy time to prepare and accumulate resources to adjust consumption.

We estimate the SUR model to examine the factors that affect individual MWTP estimates for the attributes of power outage. The Breusch-Pagan test of independence shows significant correlation among residuals of the several equations with a chi-square test statistic of 138.26. This implies that there is a gain in efficiency from using the joint estimation approach. For the sake of comparison, we estimated the equation-by-equation OLS and we confirm that, overall, the parameter estimates from the SUR model are more efficient than equation-by-equation OLS⁹.

The SUR model estimation indicates that all the included socioeconomic and demographics characteristics have significant impacts on MWTP for at least one attribute. Household income has a significant and positive impact on the MWTP estimates for reduced frequency of power outages, reduced duration of power outages, and getting an advance notice through text messages.

⁹ Results of the equation-by-equation OLS estimation is available from authors upon request.

Figure 2. MWTP for the power outage attributes by income

For instance, this implies that for a household faced with a 3-hour long power outage, a one-percentage increase in income of the household increases the MWTP for a reduction of an extra hour in the length of power outages by around 0.02 ETB. We also find that age has a significant and negative impact on MWTP estimates for reduced frequency of power outages, and to get notification via text messages. This implies that the older the members of a household, the lower the MWTP to reduce frequency of power outage and to get notification via SMS. A possible explanation is that older people may have bad experiences with the current electricity authority and thus may have less confidence in the provision and implementation of the outlined policies. Hence, aged households may greatly rely on other energy sources such tradition fuels.

Household size has a significant and positive effect on the MWTP to avoid power outages that occur during weekends. This may be because most households would consider weekends as leisure time that is spent together with the family, cooking, watching TV, and doing other energy-consuming activities at home.

The second category of variables is the type of fuels used and their prices. The rationale behind including the fuel types is that the type of fuels that are currently used as main fuel may affect the MWTP for reducing power outages.

Table 5. Determinants of the MWTP for the attributes of power outage from SUR model estimation

Variable	MWTP to reduce frequency of power outages	MWTP to reduce duration of power outages	MWTP to avoid weekend power outages	MWTP to get a week prior notice of power outages	MWTP to get a power outage notice via SMS
Log (income)	3.986* (2.229)	6.005*** (2.28)	0.764 (3.124)	1.469 (1.097)	5.282* (2.986)
Age	-0.294*** (0.108)	-0.213 * (0.111)	-0.11 (0.169)	-0.053 (0.054)	-0.316** (0.156)
Education	-0.292 (0.283)	-0.439 (0.291)	-0.417 (0.442)	-0.074 (0.141)	0.539 (0.428)
Household size	0.807 (0.679)	0.327 (0.682)	2.277** (1.102)	0.504 (0.321)	
Wood	-1.249	-1.791		-4.087**	-9.574**

	(4.096)	(4.139)		(1.986)	(4.51)
Wood	0.014	0.0002		0.018**	
expenditure	(0.018)	(0.018)		(0.009)	
Electricity	0.006	9.518**		4.189**	5.829
	(3.932)	(4.01)		(1.942)	(5.637)
Electricity	-0.031**	-0.014		-0.015**	
bill	(0.015)	(0.015)		(0.007)	
Share	-10.237***	-5.404**		0.844	
electricity	(2.452)	(2.445)		(1.156)	
Experience	10.669***	6.918**	17.346***	1.842	13.785***
	(2.732)	(2.801)	(3.88)	(1.35)	(3.852)
Refrigerator	7.708**	-0.402		-1.803	
	(3.023)	(3.014)		(1.425)	
TV	-9.344*	2.774	0.353	1.821	
	(5.033)	(5.053)	(7.943)	(2.376)	
Mobile	13.685**	13.367**		8.302***	15.242 *
	(5.748)	(5.873)		(2.85)	(8.578)
Environment	3.787	-2.328		1.987*	
al pollution	(2.562)	(2.555)		(1.208)	
Intercept	-10.912	-47.77***	-8.968	-17.826**	-59.268**
	(17.613)	(18.034)	(24.318)	(8.684)	(24.314)
R-squared	0.278	0.221	0.13	0.255	0.188

Note: Standard errors are in parenthesis. ***, **, * indicate significance levels at 1%, 5%, and 10%, respectively.

Results suggest that households using wood as their main cooking fuel have relatively low MWTP to reduce power outages, and low MWTP to get one week's prior notice and notification via SMS. Not surprisingly, households relying on electricity as their main cooking fuel have higher MWTP for reduced duration of power outages and to get a week's prior notice. Moreover, the costs of wood and electricity also affect MWTP for attributes of power outage as might be anticipated. An increase in wood expenditure leads to increase in MWTP for improvements of the electricity supply service through MWTP to get a week's prior notice. Conversely, an increase in the monthly electricity bill decreases the MWTP for reduced frequency of power outages as well as the MWTP to get a week's prior notice. This is in line with own price and cross price elasticity concepts in the theory of demand. Since the service under consideration is electricity, an increase in electricity bill affects it negatively while an increase in the price of wood affects it positively.

The third category of variables comprises appliances ownership. The expectation is that households who own appliances that function with electricity may have higher MWTP for the attributes of electricity supply service. The SUR estimation results confirm that owning a refrigerator in the household has a positive effect on MWTP to reduce frequency of power outages. Besides, mobile phone ownership has a positive effect on MWTP to reduce frequency of power outages, reduce duration of power outage, get a week prior notice and get notification via SMS.

Other variables such as experience, sharing electricity, and environmental concern also appear to affect MWTP for the attributes of power outage. Households that have had bad experiences as

a consequence of power outages (e.g., constrained to freely move outside home) have a higher MWTP to reduce the frequency of power outages, reduce duration of power outage, to avoid weekend power outages, to get a weeks prior notice and to get advance notice via SMS. On the contrary, electricity subscriber households who are sharing electricity with other households have lower MWTP to reduce frequency and duration of power outages. This may indicate that the electricity subscriber households who share electricity with their neighbors may believe that the households with whom they are sharing electricity should also contribute their fair share for the improvement of electricity services. Moreover, environmental concern has a positive effect on preferences for improved electricity service, as it is associated with a higher MWTP to get a week prior notice. A possible explanation for this is that environmentally concerned households prefer and are willing to pay to get a week prior notice, so they will adjust their cooking e.g. by baking non-perishable foods in advance, and this subsequently reduces pressure on the environment as the use of fuelwood can be avoided.

6. Conclusion

This paper addresses the relative importance of different aspects of power outage (duration, frequency, timing), and whether it is possible to make outages more acceptable by providing advance notice. This paper also aims at identifying the factors that determine households' MWTP to reduce the different negative aspects of power outages. To answer these research questions, we conducted a DCE based on interviews with urban households in Ethiopia.

The results indicate that frequent, long and weekend power outages make households shy away from fully switching to electricity. The decreasing relationship between the MWTP estimates and the frequency and length of power outages indicate that households are less sensitive to additional reductions of power outages when they are subject to relative frequent and

long-lasting power outages, but if reliability is improved, their sensitivity to additional reductions increases. This implies that households are more likely to rely entirely on traditional fuels for cooking when the power outages are frequent and long. Moreover, planned power outages are acceptable if advance notice is provided at least a week in advance. Hence, this increases reliability of the electricity supply, which may in turn increase households' propensity to switch fully from fuelwood to electricity. These findings offer an explanation why the vast majority of the urban population in developing countries still relies on traditional fuels for cooking despite having access to electricity. We also find that household characteristics (income, age, and household size), type and price of fuels for cooking, experience, sharing electricity with others, ownership of electrical appliances, and environmental concern influence households' MWTP to reduce power outages through at least one attribute of power outage.

The output of this study is an important input to policy makers aiming to speed up the process of fuel switching. Reliability of electricity supply needs a due consideration from policy makers (and stakeholders) in developing countries. Due to the rapid electrification rate in developing countries, the main focus of the current energy targets aims at ensuring electricity access and promoting the use of electricity (from renewable energy) for cooking so as to reduce the health and environmental problems associated with the use of traditional fuels. However, such policies will be suboptimal if they do not take the reliability of electricity into consideration. Hence, we argue that once the reliability of electricity is ensured, the switch to electricity based new technologies for cooking is likely to increase rapidly.

Appendix A: Supplementary material

7. References

- [1] UN-SDG 7. Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all, <http://www.un.org/sustainabledevelopment/energy/>. 2018.
- [2] Arnold JEM, Köhlin G, Persson R. Woodfuels, livelihoods, and policy interventions: Changing Perspectives. *World Development*. 2006;34(3):596-611.
- [3] Bhattacharyya SC. Energy access programmes and sustainable development: A critical review and analysis. *Energy for Sustainable Development*. 2012;16(3):260-71.
- [4] World Bank. World Bank Supports Ethiopia's Endeavors to Provide all Citizens with Access to Electricity, <https://www.worldbank.org/en/news/press-release/2018/03/01/world-bank-supports-ethiopias-endeavors-to-provide-all-citizens-with-access-to-electricity>. 2018.
- [5] Hutton G, Rehfuess E, Tediosi F. Evaluation of the costs and benefits of interventions to reduce indoor air pollution. *Energy for Sustainable Development*. 2007;11(4):34-43.
- [6] IEA. *World Energy Outlook 2006 (Summary)*. Paris: OECD Publishing; 2006.
- [7] Abebaw D. Household Determinants of Fuelwood Choice in Urban Ethiopia: a Case Study of Iimma Town. *The Journal of Developing Areas*. 2007;41(1):117-26.
- [8] Gebreegziabher Z, Mekonnen A, Kassie M, Köhlin G. Urban energy transition and technology adoption: The case of Tigray, northern Ethiopia. *Energy Econ*. 2012;34(2):410-8.
- [9] Mekonnen A, Köhlin G. Determinants of Household Fuel Choice in Major Cities in Ethiopia. *Environment for Development: Discussion paper series*. Göteborg, Sweden: University of Gothenburg; 2008. p. 1-23.
- [10] van der Kroon B, Brouwer R, van Beukering PJH. The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews*. 2013;20:504-13.
- [11] Andersen TB, Dalgaard C-J. Power outages and economic growth in Africa. *Energy Econ*. 2013;38:19-23.
- [12] Kaseke N, Hosking SG. Sub-Saharan Africa Electricity Supply Inadequacy: Implications. *Eastern Africa Social Science Research Review*. 2013;29(2):113-32.
- [13] Rosnes O, Shkaratan M. *Africa's power infrastructure: investment, integration, efficiency*: World Bank Publications, 2011.
- [14] Gertler PJ, Lee K, Mobarak AM. Electricity Reliability and Economic Development in Cities: A Microeconomic Perspective. In: *Series ES-o-KP*, editor. 2017.
- [15] MoFED. *Growth and Transformation Plan: Annual Progress Report for FY 2012/13*. Addis Ababa: Ministry of Finance and Economic Development; 2014.
- [16] de Nooij M, Koopmans C, Bijvoet C. The value of supply security. *Energy Econ*. 2007;29(2):277-95.

- [17] Devicienti F, Klytchnikova I, Paternostro S. Willingness to pay for water and energy: an introductory guide to contingent valuation and coping cost techniques. Energy Working Notes World Bank, Washington, DC. 2004.
- [18] Abdullah S, Mariel P. Choice experiment study on the willingness to pay to improve electricity services. Energy Policy. 2010;38(8):4570-81.
- [19] Amador FJ, González RM, Ramos-Real FJ. Supplier choice and WTP for electricity attributes in an emerging market: The role of perceived past experience, environmental concern and energy saving behavior. Energy Econ. 2013;40:953-66.
- [20] Carlsson F, Martinsson P. Willingness to pay among Swedish households to avoid power outages: a random parameter Tobit model approach. The Energy Journal. 2007:75-89.
- [21] Carlsson F, Martinsson P. Does it matter when a power outage occurs? — A choice experiment study on the willingness to pay to avoid power outages. Energy Econ. 2008;30(3):1232-45.
- [22] Hensher DA, Shore N, Train K. Willingness to pay for residential electricity supply quality and reliability. Applied Energy. 2014;115:280-92.
- [23] Layton DF, Moeltner K. The cost of power outages to heterogeneous households. In: Scarpa R, Alberini A, editors. Applications of Simulation Methods in Environmental and Resource Economics: Springer; 2005. p. 35-54.
- [24] Baarsma BE, Hop JP. Pricing power outages in the Netherlands☆. Energy. 2009;34(9):1378-86.
- [25] Heltberg R. Fuel switching: evidence from eight developing countries. Energy Econ. 2004;26(5):869-87.
- [26] Dubin JA, McFadden DL. An econometric analysis of residential electric appliance holdings and consumption. Econometrica: Journal of the Econometric Society. 1984:345-62.
- [27] Lancaster KJ. A new approach to consumer theory. The journal of political economy. 1966:132-57.
- [28] Bateman IJ, Carson RT, Day B, Hanemann M, Hanley N, Hett T, et al. Economic valuation with stated preference techniques: a manual. Cheltenham, UK: Edward Elgar, 2002.
- [29] Hoyos D. The state of the art of environmental valuation with discrete choice experiments. EcolEcon. 2010;69(8):1595-603.
- [30] Bennett J, Birol E. Choice experiments in developing countries: implementation, challenges and policy implications. Cheltenham, UK: Edward Elgar; 2010.
- [31] Kassahun HT. Advances in stated preference studies for valuing and managing the environment: a developing country context. Copenhagen, Denmark: University of Copenhagen, 2014.
- [32] Hensher D, Shore N, Train K. Households' Willingness to Pay for Water Service Attributes. EnvironResourEcon. 2005;32(4):509-31.

- [33] Yin RK. Case study research: Design and methods London and Singapore: Sage Publications, 2003.
- [34] ChoiceMetrics. Ngene 1.1.1 User Manual & Reference Guide, . Australia 2012.
- [35] Carson RT, Louviere JJ, Anderson DA, Arabie P, Bunch DS, Hensher DA, et al. Experimental analysis of choice. *Marketing letters*. 1994;5(4):351-67.
- [36] Ladenburg J, Olsen SB. Gender-specific starting point bias in choice experiments: Evidence from an empirical study. *Journal of Environmental Economics and Management*. 2008;56(3):275-85.
- [37] USAID. Power Africa in Ethiopia: Fact sheet, <https://www.usaid.gov/powerafrica/ethiopia>. 2018.
- [38] Ministry of Water and Energy M. Scaling - Up Renewable Energy Program in Ethiopia Investment Plan. 2012.
- [39] Hailu HK. Ethiopia - Electrification Program for Results (English). Washington, D.C. : World Bank Group. <http://documents.worldbank.org/curated/en/347061503651051401/Ethiopia-Electrification-Program-for-Results>. 2017.
- [40] Gordon E. The Politics of Renewable Energy in East Africa. Oxford Institute for Energy Studies; 2018.
- [41] Ethiopian Electric and Power Corporation Northern District. Number of active customers Data and their Tariff Categories of Mekelle Districts. Mekelle, Ethiopia: Northern Region Marketing section; 2014.
- [42] Central Statistical Agency, ICF Demographic and Health Survey. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF; 2016.
- [43] Train KE. Discrete choice methods with simulation: Cambridge university press, 2009.
- [44] Greene W. NLOGIT Version 5 Reference Guide: Econometric Software, Inc., 2012.
- [45] Hole AR. A comparison of approaches to estimating confidence intervals for willingness to pay measures. *Health Econ*. 2007;16(8):827-40.
- [46] Lancsar E, Savage E. Deriving welfare measures from discrete choice experiments: inconsistency between current methods and random utility and welfare theory. *Health Econ*. 2004;13(9):901-7.
- [47] Cameron AC, Trivedi PK. Microeconometrics: methods and applications. New York, USA: Cambridge university press, 2005.
- [48] Campbell D. Willingness to Pay for Rural Landscape Improvements: Combining Mixed Logit and Random-Effects Models. *Journal of Agricultural Economics*. 2007;58(3):467-83.
- [49] StataCorp. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP. 2015.
- [50] Moeltner K, Layton DF. A censored random coefficients model for pooled survey data with application to the estimation of power outage costs. *Review of Economics and Statistics*. 2002;84(3):552-61.

- [51] Ladenburg J, Jensen KL, Lassen C. Does it matter why power outages occur? An example of information-induced gender-heterogeneous preference on the intensive and extensive margins of choice. *Applied Economics Letters*. 2014;21(10):657-64.
- [52] Cheng C-y, Urpelainen J. Fuel stacking in India: Changes in the cooking and lighting mix, 1987–2010. *Energy*. 2014;76:306-17.
- [53] Mekonnen A, Köhlin G. Determinants of household fuel choice in major cities in Ethiopia. 2009.
- [54] Tversky A, Kahneman D. The Framing of Decisions and the Psychology of Choice. *Science*. 1981;211:30.

Highlights

- We study households' valuation of reliability of electricity in developing country
- We conducted a choice experiment with a sample of urban households in Ethiopia
- We combined mixed logit and seemingly unrelated regression models for the analysis
- Unreliable electricity make households shy away from fully switching to electricity
- Income, age, type and price of fuels are among the determinants of households' MWTP