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Households' valuation of power outages in major cities of Ethiopia: An application of stated preference methods[☆]

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ABSTRACT

In many developing countries, electricity consumers experience frequent supply interruptions, leading to high coping costs and stifled investment, which contribute to energy poverty. In 2019, we implemented stated preference experiments to estimate households' preferences for improved electricity supply in a nationally representative sample of urban households, covering 42 cities in Ethiopia. In the first split-sample experiment, we presented respondents with a contingent valuation (CV) scenario that alternatively elicited their willingness to pay (WTP) for reduced evening-time power outages, or their willingness to accept (WTA) compensation for increased disruptions. Then, we implemented a discrete choice experiment with the same respondents to understand preferences for the frequency, duration and time of a day attributes of outages, as well as the value of advanced notification. The results from the CV survey show that household WTP is approximately 40 birr (US $1.4) for a three-hour reduction of duration in power outages in the evening and that WTA is 42 birr (US$1.4) for a similar increase in the duration of outages during that period. The choice experiment meanwhile reveals that household WTP is 11 birr (US$0.4) for a one-unit reduction in the number of outages and 53 birr (US$1.8) to avoid daytime or nighttime outages relative to morning outages, on average. Households prefer a day prior outage notification to a week prior notification, with a marginal WTP of 23 birr (US$0.8). Information about the value of such outage attributes can help inform strategies that better address electricity consumers' preferences and needs. We finally discussed the relationship between energy poverty and preferences for improved electricity supply.

1. Introduction

There has been rapid recent progress in electrification in many low-income countries although that progress is uneven within and across countries (Falchetta et al., 2020; IEA et al., 2020; Marwah, 2017). Moreover, electricity supply for those connected in such settings often remains highly unreliable (Cole et al., 2018; World Bank, 2018). Frequent and long-lasting disruptions of electricity supply, both predictable (e.g., due to regular load shedding) and unpredictable (e.g., from equipment failure or overloaded transmission and distribution infrastructure), force households and enterprises to maintain a stock of alternatives that raise the cost of their energy services, and decrease firm

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competitiveness (Grimm et al., 2013; Frederick and Selase, 2014; Occhiali, 2017). These coping costs include purchase and operation of diesel generators, back-up batteries, and other equipment that runs on alternative fuels, such as charcoal, fuelwood, kerosene and LPG, many of which are also highly polluting (Meles, 2020). Additionally, households must cope with productivity loss for activities that are curtailed, with damaged electric appliances (from recurrent outages and voltage surges), insecurity at night, and children being unable to study after the sun goes down. These myriad coping costs harm economic development and may perpetuate energy poverty even as many goals for electricity access and affordable tariffs are realized.

The private and social costs of unreliable electricity can be reduced with investment in increased generation capacity, more robust transmission and distribution infrastructure, and enhanced utility management. However, such improvements entail significant costs that may be hard to finance or otherwise create long-term sustainability challenges, especially where tariffs are kept well below levels needed for cost recovery (McRae, 2015). Ethiopia is a prototypical example: tariffs have historically been kept very low even in the face of harmful disruptions, and energy poverty is among the highest in the world (Nussbaumer et al., 2012). According to the Reliability-Adjusted Cost of Electricity (RACE) metric (Energy for Growth Hub, 2019), Ethiopia has the second largest gap between actual tariffs and the cost of electricity borne by industry, which must heavily rely on alternatives. Moreover, decision-makers are often hamstrung in prioritizing electricity service quality improvements due to a lack of understanding of the full consequences of existing system deficiencies. A key challenge in assessing the costs and benefits of unreliable electricity is that the adverse effects of power outages on consumers are not readily reflected in market prices. It is well understood, for example, that revealed preference measures such as coping or averting costs represent only a partial accounting of these costs (Beenstock, 1991), for a range of reasons including technology limitations (Pattanayak et al., 2005), credit constraints (Carlsson et al., 2020), or differences in the quality of those alternatives (Orgill-Meyer et al., 2018). These aspects are likely to be especially binding for the energy poor, who have limited resources to invest in alternatives. For this reason, measures such as the RACE metric may actually understate both the true cost of poor quality power and the policy case for improved reliability.

When considering complex valuation challenges with market and nonmarket consequences, economists therefore typically use stated preference methods to obtain more complete measures of economic value (Adamowicz et al., 1994). In such studies, carefully designed survey questionnaires built around hypothetical scenarios or situations are used to directly elicit respondents' preferences for specific changes in the quantity or quality of services. To that end, in 2019, we implemented dual methods to estimate the value that urban households attach to reduced power outages in Ethiopia: the contingent valuation (CV) method and the discrete choice experiment (DCE). We particularly focus on variation and consistency of these valuation measures according to different definitions of energy poverty, which on the one hand, may limit demand, or simply reflect a high dependence on costly substitutes (and therefore boost demand).

More specifically, the DCE allows examination of the value that urban Ethiopian households attach to changes in the various attributes of outages, namely a) reduced frequency, b) shorter duration, c) the time of a day of such disruptions, and d) advanced notification of outage events. The CV surveys meanwhile allow us to examine the symmetry of households' value function – as determined by randomized willingness to pay (WTP) and willingness to accept (WTA) framings – around a change (decrease and increase) in duration of outages in the evening by three hours. The WTP framing allows estimation of the value that households attach to a three-hour reduction in the duration of power outages in the next week, while the WTA framing indicates the compensation that would be required for households to be equally well off given a similar increase in the next week's duration of outages. We additionally test, using an experiment that is orthogonal to that for the framing of the survey, whether the inclusion of a script meant to emphasize the policy consequentiality (i.e., respondents' believe that the survey results will be considered by policymakers) has any influence on respondents (Needham and Hanley, 2020). For this, respondents in the policy consequences group were provided a formal letter from the single and state-owned electricity utility, Ethiopian Electric Utility, that stated that the results of the study would be considered in future decisions regarding electricity supply in Ethiopia.

We further assess the role that energy poverty plays in demand for improved electricity service. Energy poverty in its broader sense is defined as people's inability to afford or access quality energy services to meet basic needs, although no consensus exists in the literature regarding the definition or how to measure it (Boardman, 1991; Best and Sinha, 2021; Churchill and Smyth, 2020). In the context of developed countries, people's inability to afford electricity and gas for heating or cooling is a key aspect of energy poverty whereas in developing countries the literature focuses on absence and poor supply of electricity, which forces people to rely on biomass and less clean energy sources (Zhang et al., 2021; Phoumin and Kimura, 2019; Thomson et al., 2017). Empirical studies adopt different measures of energy poverty such as the proportion of households whose spending on energy exceeds 10% of income (Boardman, 1991; Churchill and Smyth, 2020), the multidimensional energy poverty index (Nussbaumer et al., 2012; Churchill and Smyth, 2020; Ssennono et al., 2021; Zhang et al., 2021), as well as subjective measures (Thomson et al., 2017; Churchill et al., 2020). Each indicator of energy poverty has different pros and cons.[1]

In light of the considerable controversy over definitions and measures of energy poverty in the literature (Boardman, 1991; Pachauri and Spreng, 2004; Nussbaumer et al., 2012; Churchill et al., 2020; Ssennono et al., 2021), we construct three distinct indicators of energy poverty from our data. The first is meant to indicate a high relative burden of energy cost: specifically, a household is classified as energy poor if it spends more than 10% of its total expenditures (a proxy measure of income) on fuels including electricity (Boardman, 1991). Like food expenditure-based poverty indicators, this measure has intuitive appeal for measuring energy poverty. However, it may simply identify households who use a lot of energy, and does not account for the fact that such households may also have a higher income than those who spend little on electricity. The second measure applies a very different logic and gives more weight to the type of energy use; as such it is closer to coping cost-based indicators (Mirza and Szirmai, 2010; Practical Action, 2010). Given the high cost of polluting fuels, in terms of low time efficiency, health costs, and aesthetic disamenities (Jeuland et al., 2015; Jeuland et al., 2018), it identifies a household as energy poor if it spends more on polluting fuels (namely solid fuels and kerosene) than it does on electricity. As such, it may better capture the situation of access- or budget-constrained households who are unable to use large amounts of electricity. Finally, the third measure is purely based on the poverty status of the household and classifies a household as energy poor if it has per capita expenditures that fall below an internationally recognized poverty line of $1.9 per person per day (Ferreira et al., 2016). While this measure is not energy-situation specific, the economically poor are much more likely to be energy poor, given the high correlation between income and energy poverty (Nussbaumer et al., 2012).

We are not the first to use stated preference methods to elicit

[1] For instance, the unidimensional expenditure-based measure captures a narrow aspect of energy poverty and is likely to overestimate or underestimate the incidence rate of energy poverty although it is easy to interpret. On the other hand, the multidimensional energy poverty index approach does not consider inequality and its distributional aspects among the energy poor. Similarly, the subjective measures that capture self-reported indicators are not only unreliable but also susceptible to errors of exclusion. See, Ssennono et al. (2021) for an up-to-date discussion on the various measures of energy poverty.

household preferences for improved electricity supply. For example, Beenstock et al. (1998), Layton and Moeltner (2005), Carlsson and Martinsson (2007), Meles (2020), Oseni (2017), Cohen et al. (2018), and Amoah et al. (2019) apply the CV method to this problem, while Carlsson and Martinsson (2008), Abdullah and Mariel (2010), Pepermans (2011) and Ozbafli and Jenkins (2016) employ DCE. However, our study adds to this literature in four key ways. First, we provide the first examination of the relationship between demand for electricity quality and energy poverty status, which is important for better understanding the distributional implications of policies to improve reliability. By doing so, our study contributes to the recent literature that investigates the effects of energy poverty, for example, on subjective wellbeing (Churchill et al., 2020; Druică et al., 2019), social wellbeing (Phoumin and Kimura, 2019), children wellbeing (Zhang et al., 2021) and health (Thomson et al., 2017; Churchill and Smyth, 2021), by focusing on the demand for quality of electricity service. Understanding the role of energy poverty in demand for improved quality of electricity service has important policy implications because energy poor households are most likely to suffer the adverse effects of outages due to limited coping capacity. Also, these households are generally expected to have lower WTP for outage reduction, which highlights the low equilibrium trap that the poor and marginalized often face: high-quality services are difficult to support when WTP is low. Breaking this cycle requires additional intervention to empower such households.

Second, as far as we know, ours is the first WTP comparison of the CV and DCE methods in the context of electricity reliability. Such a comparison is valuable given that the CV method focuses respondents' attention on a specific improvement scenario that can seem more concrete, and yet preferences for enhanced electricity reliability may vary along multiple dimensions, which are best examined using a DCE. Third, we add to the existing literature on the divergence between WTP and WTA measures of demand, which may be especially important for the energy poor who may have a particularly asymmetric value owing to budget constraints that inhibit WTP. In this sense, the study contributes to a broader literature that compares CV and DCE methods (Boxall et al., 1996; He et al., 2017), and that explores WTP-WTA disparities (Tunçel and Hammitt, 2014; Kim et al., 2015). Finally, from a policy perspective, our study is unique in covering a nationally representative sample of urban households, covering 42 cities in Ethiopia, which is an important country in Sub-Saharan Africa. Ethiopia is important both in terms of population and ambitious targets for universal electrification, including better quality of electricity supply (MoWIE, 2019; Jodensvi and Torstensson, 2020; Meles, 2020). Compared with other related studies (see, e.g., Abdullah and Mariel, 2010; Carlsson and Martinsson, 2007; Pepermans, 2011; Ozbafli and Jenkins, 2016; Zemo et al., 2019; Amoah et al., 2019; Meles, 2020), our study is conducted with a relatively large and nationally representative sample of urban households.

The rest of the paper is organized as follows. Section 2 presents the data and methodology. Section 3 presents the results and the discussion. Section 4 provides the conclusion.

2. Data and methodology

2.1. Data

Our data comes from a nationally representative urban household survey conducted in 2019 that builds on a prior Multi-Tier Framework (MTF) survey effort administered in Ethiopia by the World Bank in 2016, which enrolled a nationally representative sample that also included rural areas. Padam et al. (2018) provide details on the sampling procedures used in the first round. The first-round sample was used as the basis for construction of the second-round survey that focuses exclusively on urban enumeration areas.[2]

In the second round survey for Addis Ababa, in addition to all households that had been enrolled in the first round MTF survey, 400 additional households who had recently obtained connections based on prepaid metering were enrolled to allow consideration of new urban energy consumers. This approach allowed us to update the sample to account for rapid urbanization and to study the energy use patterns of prepaid electric-meter customers since all new connections in Addis Ababa now receive this pre-paid metering system. It also enables a richer analysis of the reliability preferences of customers in the traditional post-paid and new pre-paid system, who may use electricity in very different ways. We used a two-step procedure to select these new prepaid meter respondents. In the first stage, an equal number of prepaid customers was considered from each of the four regions (North, South, East, and West) of Addis Ababa, and applied a simple random sampling (lottery method) to select one center from each region.[3] In the second stage, we used randomization (in MS Excel) to select 100 households from each of the four regions from the list of all residential prepaid electric-meter customers. Prepaid meters are not yet installed outside of Addis Ababa.

Overall, our study covers a sample of over 2180 urban households from 42 cities in Ethiopia, covering seven regions (of the nine regional states) and the two administrative cities (i.e., Addis Ababa and Dire Dawa). Fig. 1 shows the map of the urban areas in Ethiopia that are covered in our study. About 54% of the sample is from Addis Ababa, the capital of Ethiopia, while the remaining are from the other sample cities in the seven regional states and Dire Dawa city.[4] Table A.1 in the appendix provides the list of the sample cities with their corresponding sample and population sizes. The household survey was administered

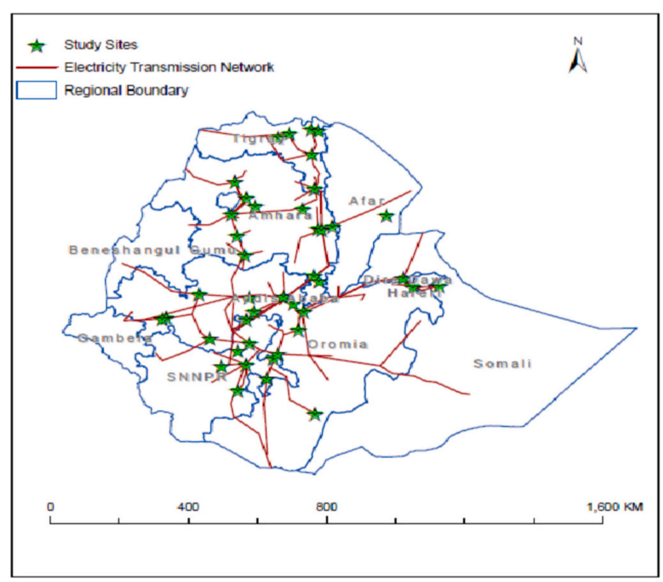

Fig. 1. Map of the study areas.

[2] Our survey is part of an Energy and Economic Growth (EEG) project supported by DfID and conducted by Policy Studies Institute of Ethiopia.

[3] The electric power distribution in Addis Ababa comprises four regions (North, South, West and East). Within each region, there are a number of smaller administrative units called centers. The number of centers depends, among others, on the number of customers and hence varies from district to district.

[4] The share of the sample from Addis Ababa is a bit larger than the share of the population of Addis Ababa relative to the total population of the cities included in the sample (which is about 41%).

from August to October 2019 through face-to-face interviews using computer-assisted personal interviews (CAPI). It was carried out by a group of 35 well-trained and experienced fieldworkers, consisting of 30 enumerators working under the close supervision of five supervisors. The authors were responsible for monitoring the progress of the field survey.

The survey questionnaire contains, among others, detailed information on household socio-demographic characteristics, source of electricity, electricity tariff, and fuel consumption. The DCE was presented after asking questions on electricity sources and collecting information on the electricity tariff. The WTP and WTA questions were then asked following the DCE. Before the main survey, we carried out pilot tests to understand the situation regarding electricity supply and to obtain preliminary data on WTP and WTA using open-ended value elicitation questions, which were used to specify the bids in the final survey. Following standard practice, respondents were informed about the general purpose of the survey and were asked to express their willingness to participate in the survey.

2.2. Design of the stated preference surveys

As noted above, we used both discrete choice experiment (DCE) and contingent valuation (CV) methods to elicit households' valuation for changes in power outages. The design of the DCE and the CV are discussed in detail below.

2.2.1. Design of the DCE

We determined attributes and their levels based on previous literature, previous data collected from the households covered in the study (in the baseline MTF survey), as well as a pilot test. We identified five attributes including the *payment*. The four non-price attributes related to the outages are reduction in *frequency*, *duration*, *notification* (before outages), and *time of a day outages occur*. The payment attribute was presented as a percentage increase in the monthly electricity bill given the proposed improvements and outage characteristics; this was then converted into an amount in Ethiopian *birr* based on household-specific billing data that was collected as part of the survey.[5] In each choice set of the DCE, three alternatives were presented to sample households including the status quo. The levels of the attributes used in the pilot survey were informed by previous literature and by the electricity supply characteristics as measured in the MTF sample, in order to represent realistic changes in outage frequency and duration. As shown in Table 1 below, the final list of attributes and their levels were specified after the pilot survey based on preliminary results.

Considering the number of attributes and levels used in the study, a full factorial design would have yielded too many choice sets, so we used Stata 15 to obtain an orthogonal experimental design for identifying main effects (Hensher et al., 2005). The design generated twelve choice sets that were split into two blocks of six and randomly assigned to respondents.

As part of the preamble to the DCE, enumerators informed respondents that power outage problems in Ethiopia are mainly caused by limited power generation, poor power distribution or transmission systems (due to old age of the systems and lack of sufficient maintenance), and limited system capacity relative to increasing demand. The need for investment to address the problem by increasing power generation capacity and improving the power distribution and transmission systems was noted. The benefits of such investment were specifically mentioned to respondents in terms of reducing the frequency and duration of power outages and covering costs of proactively notifying customers about

Table 1
Attributes and their levels for the status quo and proposed alternatives.

Attributes	Status quo	Levels for alternatives 1 and 2
Duration of power outages in hours	5 h	1, 3, 4 h
Frequency of power outages per month	8 times	1, 3, 6 times
Time of a day outages occur	Any time	6 pm to 10 pm (evening –peak load), 9 am to 6 pm and 10 pm to 5 am (outside morning and evening), and 5 am to 9 am (morning peak load)
Notification of customers about a power outage	No notification	One day prior notification, one-week prior notification
Increase in monthly electricity bill	No increase in your electricity bill	25%, 50%, 75% and 100% increase in your electricity bill

power outages.

Respondents were explicitly informed of the four attributes identified in addition to the payment attribute (see Fig. 2 for a sample choice set). Reminders of the budget constraint were provided by noting that when the respondent pays for the improvements in electricity service, the money would not be available to pay for other purposes. A “cheap talk” script was included to encourage them to consider the choice seriously (Cummings and Taylor, 1999). In addition, respondents were reminded that proposed improvements would be implemented if these were supported by a majority of respondents, to avoid free-riding on this quasi-public good improvement. Please see Annex 1 for the full DCE script. Respondents were allowed to ask questions to clarify any issues they found to be confusing or unclear.

The DCE also included follow-up questions that examined the degree to which respondents paid attention to each of the five attributes (to examine attribute non-attendance). Follow-up questions then probed the extent to which respondents were certain about their choices, and the reasons behind their choices, including opting for the status quo.

2.2.2. Design of the CV experiment

The CV part of the questionnaire included two split-sample experiments: The WTP/WTA framing experiment, and a policy consequentiality experiment. Respondents were randomly assigned to one of the WTP/WTA questions, which both relied on a single-bounded value elicitation format as described above. The single-bounded format was deemed preferable due to concerns about respondent fatigue following completion of the DCE and other survey questions. On the basis of responses to open-ended valuation questions in the pilots, the bid levels used for both the WTP and WTA questions were *birr* 5, 10, 20, 50, and 100.

The CV portion of the survey also included a second split-sample experiment to examine the role of policy consequentiality, randomized independently of the WTP/WTA assignment. Thus, the CV study included four versions with the whole sample divided into four randomly selected groups of households: WTP with and without policy consequentiality, and WTA with and without policy consequentiality.

Similar to the DCE, a cheap talk script was presented, and reminders of the budget constraint were made. In both formats, the reasons for power outage problems and the need for investment and thus increases in electricity bills for reduced outages were noted. The change in outages was specified as one of reduced duration in the coming week for the WTP case and increased duration for the WTA framing. More specifically, in the WTP version, respondents were told they would receive a guaranteed *three hours of additional power supply between 6 pm and 10 pm, in the evening,* over the course of the next week if they paid a specific amount using a pay-as-you-go system. In contrast, in the WTA version, the change would be an *increase in the duration of power outages* from the

[5] Birr is the Ethiopian currency with an exchange rate of 1USD ≈ 29 birr during the beginning of the survey (August, 2019). Household-specific billing data was obtained from two sources: household survey and administratively recorded billing data from the Ethiopian Electric Utility (EEU).

Attributes	Status quo	Alternative 1	Alternative 2
Duration of power outages in hours	5 hours	1 hour	4 hours
Frequency of power outages per month	8 times	Once	Six times
Time of a day when outages occur	Any time	6:00 pm to 10:00 pm	5:00 am to 9:00am
Notification of customers about power outage	No notification	One day prior notification	One week prior notification
Increase in monthly electricity bill	No increase in your electricity bill	100% increase in your electricity bill	75% increase in your electricity bill
Respondent's preferred choice			

Fig. 2. Sample choice set.

status quo situation by *three hours anytime between 6 pm and 10 pm, in the evening,* during the coming week. It was explained that this would enable electricity supply to be increased by the same amount for other people in rural Ethiopia, even without additional generation investments. Respondents in this WTA framing were told that they would be informed in advance about outages.

In both the WTA and WTP surveys, respondents were also informed that implementation of the proposed improvements would require support by a majority of respondents. Moreover, the text that was added for the sample assigned to the policy consequentiality scenario (in the WTP version) was the following:

"You should also know that even though this is a survey, the Ethiopia Electric Utility (EEU) is considering implementing an intervention that would allow this type of electricity payment. So, if you would honestly be willing to pay and say that you would not, the utility may decide that too few people are interested to warrant the investment. On the other hand, if you answer that you are willing to pay but really are not, the EEU may devote resources to this, rather than to other projects that would also deliver electricity benefits to the population."

For WTA with policy consequentiality, the text was identical except that it was framed appropriately to pertain to the WTA survey. Please see Annex 2 for the full versions of the CV survey questions which include the versions with policy consequentiality.

2.3. Econometric approach

In choosing to value improvements in electricity reliability using DCE and CV method, we apply standard environmental valuation theory and methods (Alpizar et al., 2001; Hensher et al., 2005; Phaneuf and Requate, 2016). The random utility framework provides the theoretical basis for both the DCE and CV studies (McFadden, 1973).

In the DCE, respondents are presented with a sequence of hypothetical choice sets, each containing two or more alternatives differentiated by the levels of their attributes. Respondents indicate their preferred alternative in each such choice task. A cost attribute is commonly included in the design in order to facilitate valuation of the non-monetary attributes (in our case, duration, frequency, time of a day, and advanced notification of power outages). The utility of U_{ijt} of a respondent $i \epsilon (1, \dots, N)$ from an alternative $j \epsilon (1, \dots, J)$ in a choice set $t \epsilon (1, \dots, T)$ is the sum of a deterministic component $\beta' X_{ijt}$ and a stochastic disturbance term ε_{ijt}.

$$U_{ijt} = \beta' X_{ijt} + \varepsilon_{ijt} \tag{1}$$

where X_{ijt} is a vector of observable variables related to alternative j and respondent i and β is a vector of parameters associated with the observable variables, including alternative specific constant (ASC). Assuming that the error terms are independently and identically distributed (IID) type-I extreme value, the coefficients in Eq. (1) are estimated using a standard multinomial logit model also called conditional logit model. However, the assumption of homogeneity in preferences in the conditional logit model is restrictive and relaxed by applying the mixed logit framework.

The mixed logit (also known as the random parameter logit) model accounts for unobserved individual heterogeneity. Utility U_{ijt} in Eq. (1) is reformulated as follows to explicitly account for variations in individual tastes:

$$U_{ijt} = \beta_i' X_{ijt} + \varepsilon_{ijt} \tag{2}$$

In contrast to Eq. (1), the coefficient vector β_i varies across individuals in the population, with density function $f(\beta| \theta)$, where θ is a vector of the true parameter of the distribution. The researcher specifies the distribution of β. Under the assumption that the error terms are IID, the probability that individual i chooses alternative j in a sequence of T choices is given as:

$$P_i(\theta) = \int \prod_{t=1}^{T} \frac{exp\left(\beta_i' X_{ijt}\right)}{\sum_{j=1}^{K} exp\left(\beta_i' X_{ijt}\right)} f(\beta|\theta) \mathrm{d}\beta \tag{3}$$

The integral in Eq. (3) does not have a closed-form solution; therefore, the choice probabilities are estimated using simulation. Here, we apply 500 Halton draws to estimate the coefficients of the model (Train, 2009) using Stata software.

Since the coefficient on the cost attribute reflects the marginal utility of money, the WTP estimate for a non-monetary attribute in DCE is computed as the ratio of the coefficient of such a non-monetary attribute to the coefficient of the cost attribute (Train, 2009). However, the mean of the ratio of two randomly distributed terms derived from the mixed logit model may not always exist or may lead to unintuitive WTP estimates.[6] As such, we specify the cost coefficient to be fixed, which is a common approach in the literature.[7]

Finally, following typical practice in this literature, we consider heterogeneity in the demand for the different attributes of the DCE according to energy poverty status by interacting the binary variables for

[6] Daly et al. (2012) indicate that some popular distributions including normal, truncated normal, uniform and triangular generate infinite moments for the WTP distribution

[7] Since it is unrealistic to assume that all individuals have the same preferences for cost, an alternative approach is to specify the cost coefficient as log-normally distributed (Hole and Kolstad, 2012). This ensures that the WTP estimates have defined moments as the cost coefficient is constrained to be positive, but it may still produce unrealistic WTP estimates due to its highly skewed distribution.

each of the three energy poor indicators in our study with each DCE attribute. Examination of the significance and magnitude of these interaction terms and of the marginal WTP obtained from the ratio of attribute and cost responses provides insight into differential demand responses among households who are deemed to be energy poor.

For the CV analysis, we use a single-bounded dichotomous choice format as described in Bishop and Heberlein (1979). In this set-up, respondents are randomly offered a pre-determined bid amount (in Ethiopian birr) – selected from a set of several such amounts. Respondents are then asked if they are WTP or WTA that amount in exchange for the specific change in the quality of a hypothetical good (in our case, this is a change in the duration of electricity supply outages in the evening by three hours in the next week). Based on the random utility model, the WTP or WTA is then specified as a function of bids, other observable variables that affect WTP or WTA, and a stochastic term. With the single-bounded design, WTP or WTA is a latent variable; we observe only whether a respondent answered 'yes' or 'no' to the bid offered. The econometric model is therefore specified as follows and estimated using a probit model.

$$y_i = x_i\beta + \varepsilon_i \tag{4}$$

where the dependent variable is a dummy that equals one if a respondent i accepts the offered bid, zero otherwise. x_i and β are the observable variables that affect WTP or WTA, including the bid amount, and the associated coefficients. ε_i is the error term, which is assumed to be normally distributed, $\varepsilon_i \sim N(0, \sigma^2)$. The mean WTP and WTA are then estimated using the procedures described by Jeanty (2007) in Stata 15.

To explore how energy poverty status influences WTP and WTA, we include the three energy poor proxies in the x vector, but in separate alternative specifications of Eq. (4) (one for each energy poor proxy). Additionally, we consider the interaction of the energy poor indicators with the bid terms to test if the demand curve has a different slope among the energy poor versus non-poor.

3. Results and discussion

We present results and discussion of the DCE and CV study components, in that order. We begin by providing sample summary statistics in Table 2, discussing household characteristics and variables that are relevant to the interpretation of both the DCE and CV results, as well as energy poverty measures. About 60% of the respondents are male and 82% are literate. Around 54% of the sample resides in Addis Ababa (by far the largest city in the country). About 40% share an electric meter with other households. The average monthly electricity bill is 257 *birr* (US\$8.9) while the median monthly bill is 179 *birr* (US\$6.2).[8] The monthly electricity bill is therefore about 3.7% of the household monthly expenditures, on average. The mean electricity price per kWh is approximately 1 birr/kWh (3 US cents/kWh).

The mean number of outages reported in a typical month was 18 while the median was 8, suggesting considerable skewness in the distribution of outages across the sample. The mean total duration of outages in a typical month was 51 h with a median of 27 (again highly skewed). This implies that a typical household has about 22 h of electricity supply per day. The large difference between the mean and median frequency and duration of outages is that a number of households report very frequent and long outages, which disproportionately influence the mean. Despite the high prevalence of outages, only 3% of sample households report using a backup source of power (including batteries) during outages, this suggests that the vast majority of households are constrained to use alternative solutions for coping with interruptions.

Finally, turning to our three energy poverty measures, we see that a relatively small proportion of the sample is classified as energy poor according to the measure of fuels expenditure (including electricity bill) exceeding 10% of total expenditures (14.7%) or expenditure on polluting fuels exceeding electricity expenditure (8%). Importantly, these measures are negatively correlated, suggesting that they contain different information and identify different households as energy poor. In contrast to the first two measures, a large majority of households (69.6%) are considered poor according to the per capita expenditure benchmark of \$1.9 per day. As shown in Appendix Table A.2, households classified as poor according to the various definitions are very different from the non-poor, but the nature of the differences varies by definition.

Table 2
Summary statistics.

Variables	Obs.	Mean	Median	St.dev.	Min	Max
Respondent characteristics						
Male	2184	0.59	1	0.49	0	1
Age in years	2184	49.88	49	15.00	18	99
Not literate	2184	0.18	0	0.39	0	1
Primary education only	2184	0.37	0	0.48	0	1
High school education	2184	0.24	0	0.43	0	1
More than high school education	2184	0.21	0	0.41	0	1
Married	2184	0.59	1	0.49	0	1
Household characteristics						
Household monthly expenditures (birr)	2184	6898.2	5088.5	9524.4	214.5	25344.7
Household size	2184	4.61	4	2.03	1	14
Lives at home	2184	0.56	1	0.50	0	1
City is Addis Ababa	2184	0.54	1	0.50	0	1
Has no electric meter	2184	0.10	0	0.29	0	1
Prepaid electric meter	1975	0.27	0	0.45	0	1
Postpaid electric meter	1975	0.73	1	0.45	0	1
Shared electric meter	1975	0.40	0	0.49	0	1
Monthly electricity bill in birr (reported for last month)	1811	257.4	179.0	328.1	2.46	6872
Frequency of outages in a typical month	2152	18.15	8	21.05	0	280
Total duration of hours of outages in a typical month	2152	50.96	27.33	64.37	0	532
Has a backup source during outages	2184	0.03	0	0.17	0	1
Energy poverty measures:						
>10% expenditure on fuels	1811	0.15	0	0.35	0	1
Electricity expenditure less than polluting energy source expenditure	2184	0.08	0	0.27	0	1
Below per capita expenditure poverty line	2184	0.70	1	0.46	0	1

Note: Due to missing values or exclusion of 'irrelevant' cases, the number of observations for some variables is smaller than the total sample of 2184.

[8] At an electricity tariff during the survey period, the mean monthly electricity bill of 257 birr corresponds to 235 kWh monthly electricity consumption while the median monthly electricity bill of 179 birr is equivalent to 175 kWh monthly electricity usage.

3.1. Discrete choice experiment results

We begin our examination of the DCE results by presenting the distribution of the alternatives selected by respondents in the choice sets. Of the total choices, 41% are 'Alternative 1' and 31% are 'Alternative 2'. About 29% chose the opt-out alternative, or 'status quo' – the current situation. These raw data, therefore, indicate that respondents are usually in favor of some improvement in reliability, 'Alternative 1' or 'Alternative 2', despite the additional costs these entail.

Immediately following the choice sets, respondents were asked whether they paid attention to each of the attributes while choosing among alternatives. About 54% of the respondents claimed that they *always* paid attention to the *duration of power outages* attribute, while about 39% paid attention to this attribute in at least some instances. The attention paid to the *frequency of power outag*es and *notification of power* outages was also similar. About 54% and 38% of the respondents paid attention to the frequency of power outages always and in at least some cases, respectively, while approximately 53% and 35% of the respondents paid attention to notification of power outages always and in some cases. The results for the *time of a day* outages occur and *payment* attributes were a bit different with a relatively higher proportion of respondents stating that they always paid attention to these attributes. In particular, 60% and 33% of the respondents paid attention to the time of a day outages occur 'always' and 'in some cases', respectively. The respective percentages for the increase in electricity bill (the payment attribute) are 73% and 23%. In general, these results suggest that respondents considered the full set of attributes in at least some choice occasions, with slightly more emphasis on the outage time of day and cost attributes.

Furthermore, respondents were asked how certain they were about their choices. About 89% of respondents were either certain or very certain, while the remaining 11% were somewhat certain. Respondents who chose the status quo were also asked their reasons for opting out. About 98% of the respondents gave one of the following four answers: the high cost of the proposed improvement (79%); lack of a problem of power interruption (9%); mistrust that the proposed improvements would actually take place (7%) and a belief that having uninterrupted power supply is a right that should be provided to all, at no additional expense (3%).

Next, we present the regression results of the discrete choice experiment data. In all models, the attributes 'increase in monthly electricity bill', 'frequency' and 'duration' are specified as continuous variables whereas 'time of a day outages occur' and 'notification of outages' are specified as binary indicator variables. We also included an alternative specific constant (ASC) dummy to capture preferences for a given alternative beyond the attributes specified. The value of the ASC is equal to one if it is the 'status quo' alternative, zero otherwise. The levels of the payment attribute (which is an increase in monthly electricity bill) are presented as a percentage of their household's monthly electricity bill. For the model estimation, we converted these to absolute increments based on the self-reported latest monthly electricity bill from the survey.[9]

For comparison, we begin with the standard conditional logit model that assumes homogeneous preferences (Table 3, column 1). Columns 2–4 of Table 3 then provide the mixed logit model estimates with the cost (payment) attribute fixed and other attributes random. Columns 2 and 3 show the mean and standard deviations of the estimated coefficients, respectively, while Column 4 presents the derived marginal WTP estimates using the delta method. The values of the log-likelihood, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) indicate that the mixed logit model better fits the data. We, therefore, focus our discussion below on the mixed logit estimates.

Table 3
Discrete choice experiment estimates and corresponding marginal WTP.

Variables	(1)	(2)	(3)	(4)
Increase in monthly electricity bill	−0.002***	−0.007***		
	(0.000)	(0.0003)		
Frequency of outages	−0.069***	−0.072***	0.238***	−11.06***
	(0.007)	(0.011)	(0.019)	(1.891)
Duration of outages	0.033***	0.001	0.255***	0.17
	(0.010)	(0.016)	(0.030)	(2.285)
Evening outages (reference: daytime or nighttime outage)	0.005	0.026	0.971***	4.05
	(0.032)	(0.049)	(0.083)	(7.262)
Morning outages (reference: daytime or nighttime outage)	0.243***	0.346***	1.339***	52.79***
	(0.031)	(0.056)	(0.088)	(9.547)
Week prior outage notification (reference: day prior notification)	−0.042*	−0.150***	0.028	−22.94***
	(0.023)	(0.033)	(0.084)	(5.588)
ASC (=1 if status quo)	−0.128**	−4.139***	8.277***	−632.14***
	(0.053)	(0.295)	(0.410)	(73.678)
Log-likelihood	−11,630	−7749		
AIC	23,274	15,524		
BIC	23,332	15,633		
Observations	32,598	32,598		
Number of respondents	1811	1811		

Note: Column (1) shows results from a simple conditional logit model that imposes homogeneous preferences, whereas columns 2–4 show the mean coefficients, standard deviations, and marginal WTP estimates from a mixed logit that accommodates respondent heterogeneity. Robust standard errors clustered at the respondent level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The 32,598 observations are the eight choices of the three alternatives by the 1811 respondents.

Most of the attributes in the mixed logit are significant predictors of choices and have the expected signs. The duration attribute is the only exception in that it is not statistically significant (and even has the wrong sign in the simple conditional logit), although its standard deviation is large and significant, indicating substantial heterogeneity among sample households concerning preferences for this attribute. Otherwise, individuals prefer alternatives that have lower cost, fewer outages, outages that occur in the morning (relative to daytime or nighttime) and known outages with prior a day notification (relative to a week in advance). The estimated marginal WTP indicates that, on average, households are willing to pay about 11 *birr* (US$0.4) for one additional outage reduction per month. Fig. 3 shows the estimated marginal WTP for a reduction in the number of outages over the reported frequency of outages in a typical month at a household level. The graph indicates that the WTP for a unit reduction in the number of outages is higher at a lower reported frequency of outages than at a higher reported frequency of outages. Compared to daytime or nighttime outages, households are less willing to pay, by 53 *birr* (US$1.8), for avoiding morning outages. In contrast, evening outages are not viewed as significantly different from those occurring at other times of the day. There is significant heterogeneity among sample households for the time of a day and other outage attributes, which perhaps reflects differential time spent at home across the sample. Households are also willing to pay about 23 *birr* (US$0.8) for a day prior notification of outages compared to a week prior notification. This is perhaps due to a risk that one forgets a longer advance notification though it is expected to facilitate planning. The long advance notice could be confusing to respondents when outages are recurrent like in the case of the present study. A study by Zemo et al. (2019) also documentes that households prefer a day advance outage notification compared to three days advance notification, though it also found preference for one or two week advance notification relative to day-ahead notice.

The negative and significant coefficients of the ASC indicate that households strongly prefer improvement scenarios to the status quo,

[9] Alternatively, we use the average of the recent six months' electricity bill and the results remain unchanged.

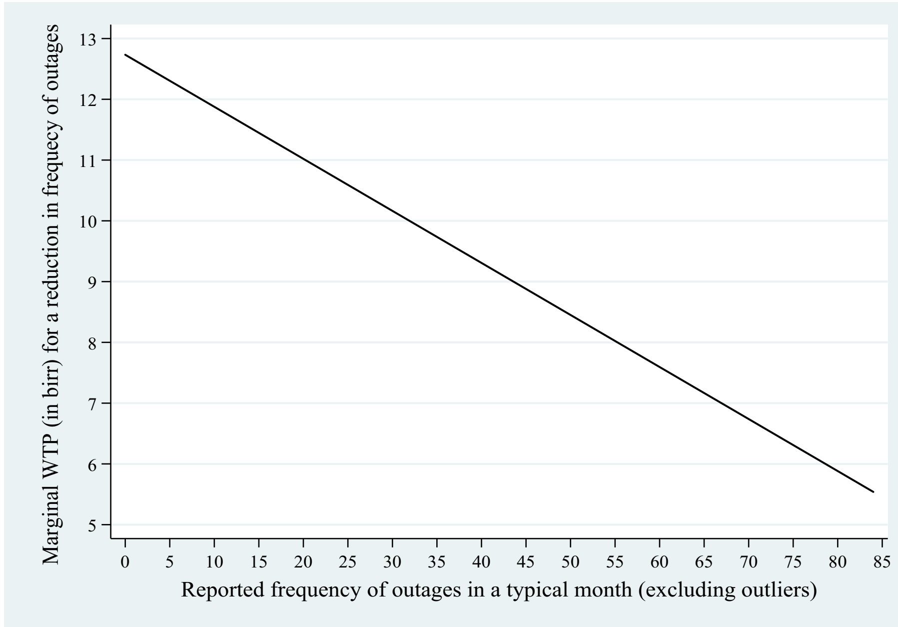

Fig. 3. Marginal WTP (in birr) for a reduction in the reported frequency of outages at a household level.

even without considering the attribute levels in the two proposed alternatives. This is in line with the results from the raw data that showed that respondents chose one of the improved alternatives in a majority of choice tasks. Overall, the estimated marginal WTP for the various attributes of power outages range from 4.3% (for a unit reduction in the number of outages per month – frequency of outages) to 20.6% (for morning outages compared to daytime or nighttime outages) of the average monthly electricity bill (US$8.9). Also, see Table A.6 in the appendix for a summary of the estimated values as a share of the monthly electricity bill.

The results in Table 3 indicate substantial heterogeneity in preferences for all but the prior notification attribute, so we next explore how preferences vary according to our three definitions of energy poverty, by including interaction terms between energy poverty indicators and the attribute levels of the discrete choice experiment.[10] Table 4 presents mixed logit model estimates with interaction terms in which all attributes except payment are again allowed to be random. Columns 1–2 are the mean and standard deviations of the estimated coefficients for poverty indicator 1 (spending more than 10% on fuels including electricity), Columns 3–4 are for poverty indicator 2 (spending more on polluting fuels than electricity), and Columns 5–6 correspond to the poverty indicator 3 (the poverty line measure). The patterns in these results are somewhat distinct across measures, but primarily related to the *payment* attribute, as we might expect. Overall, respondents still prefer alternatives with lower cost, fewer outages, morning outages, day-ahead notification, and some improvement overall. Yet energy poor households who already pay a larger proportion of their income for electricity are less sensitive to the payment attribute than the non-energy poor, while households who incur large expenses for polluting fuels or are below the poverty line are more sensitive to the payment attribute. This is especially true when using the income poverty measure, with which the non-poor are a relatively small fraction (30%) of the sample. Preferences for other attributes are not so different, except that the coefficient on the interaction of morning outages and the income poverty measure is negative and significant at the 10% level. The implied marginal WTP for the four main attributes to which respondents seem to react positively – the number of outages, the avoidance of daytime or evening outages, and the day ahead notification – is plotted for the different energy poverty subgroups in Fig. 4 This clearly shows the ambiguity in the change in demand that is associated with different conceptions of energy poverty.[11]

3.2. Contingent valuation results

As noted, respondents were randomly assigned to one of four groups for the CV portion of the survey: the WTP and WTA framings, each with and without policy consequentiality. Table 5 shows the distribution of responses to the bids across sample groups. The number of respondents in each of the four groups is approximately equal and in each of the four groups the proportion of ‘yes’ answers is about 51% while about 49% said ‘no’. Balance tests for 19 respondents' and households' characteristics suggest that the randomization was successful (see appendix

[10] We also examined heterogeneity within the sample using the conditional logit model specification by including interaction terms of the attribute levels with a variety of respondent and household characteristics (see, Table A.3 in the appendix). Overall, evidence of heterogeneity across observables is somewhat limited. However, male respondents, households with higher expenses than average expenditure, and households with prepaid meters are somewhat more sensitive to price increases. Households with educated heads and prepaid meters did not devalue morning outages as much as others (relative to a daytime or nighttime outages), while those with higher expenses than average expenditures devalue these morning outages more. Finally, households in Addis Ababa and with higher expenditure than average monthly expenditures were especially responsive (negatively) to more frequent outages.

[11] In the appendix (Table A.4), we further examine variation in preferences for the different quartiles of the energy poverty measure distributions, using the conditional logit model specification. These results generally confirm the patterns described above but provide additional nuance on the relationship between preferences and energy poverty. Specifically, we find that households in the middle two quartiles of the share of expenditure spent on fuels distribution are most sensitive to the cost of reliability improvements, which is intuitive if high fuel spenders (including on electricity) also value electricity services the most, whereas those with low fuel spending are perhaps the most income constrained or suffer from low electricity access. Households in all four quartiles highly value reduced outage frequency, regardless of the energy poverty measure used, and morning outages are deemed especially preferable (relative to other times of the day) among households in the upper quartile of per capita expenditure.

Table 4
Mixed logit estimates with interaction terms of energy poverty indicators.

	Fuels poverty		Polluting fuels poverty		Income poverty	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Increase in monthly electricity bill	−0.008***		−0.006***		−0.004***	
	(0.001)		(0.001)		(0.001)	
Frequency of outages	−0.074***	−0.245***	−0.075***	0.239***	−0.085***	0.185***
	(0.011)	(0.023)	(0.011)	(0.021)	(0.017)	(0.036)
Duration of outages	0.008	0.268***	0.001	0.260***	0.004	0.227***
	(0.016)	(0.034)	(0.016)	(0.033)	(0.025)	(0.045)
Evening outages	0.019	0.989***	−0.000	0.971***	0.041	0.943***
(reference: daytime or nighttime outage)	(0.050)	(0.094)	(0.051)	(0.091)	(0.083)	(0.092)
Morning outages	0.353***	1.346***	0.340***	1.34***	0.485***	1.199***
(reference: daytime or nighttime outage)	(0.060)	(0.095)	(0.059)	(0.099)	(0.092)	(0.127)
Week prior outage notification	−0.143***	0.017	−0.143***	0.028	−0.140***	0.007
(reference: day prior notification)	(0.033)	(0.029)	(0.035)	(0.030)	(0.050)	(0.026)
ASC (=1 if status quo)	−4.094***	8.474***	−4.17***	8.32***	−4.02***	6.81***
	(0.307)	(0.516)	(0.340)	(0.482)	(0.470)	(0.502)
Increase in electricity bill * 1 if poor	0.003***		−0.002**		−0.004***	
	(0.001)		(0.001)		(0.001)	
Frequency of outages * 1 if poor	−0.023	−0.028	0.020	0.014	0.013	0.168**
	(0.030)	(0.031)	(0.034)	(0.037)	(0.021)	(0.075)
Duration of outages * 1 if poor	−0.104**	0.192***	−0.003	0.011	−0.006	0.138
	(0.047)	(0.074)	(0.034)	(0.052)	(0.032)	(0.122)
Evening outages * 1 if poor	−0.063	−0.489	0.258	0.201	−0.037	−0.097
	(0.143)	(0.579)	(0.168)	(0.208)	(0.100)	(0.360)
Morning outages * 1 if poor	−0.016	0.130	0.083	0.117	−0.212*	0.615**
	(0.166)	(0.190)	(0.175)	(0.150)	(0.114)	(0.302)
Week prior notification * 1 if poor	0.110	0.078	−0.070	0.133	−0.001	0.004
	(0.105)	(0.165)	(0.142)	(0.221)	(0.061)	(0.045)
ASC * 1 if poor	0.668*	0.175	−0.081	0.358	−0.660	7.223***
	(0.360)	(0.553)	(0.340)	(0.687)	(0.596)	(0.635)
Observations	32,598		32,598		32,598	
Log-likelihood	−7708				-7713	

Note: Robust standard errors clustered at the respondent level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

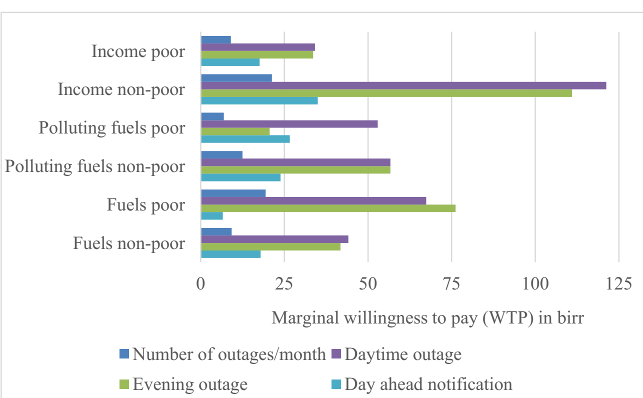

Fig. 4. Marginal WTP for specific attributes, according to energy poverty indicators and status

Table 5
Distribution of responses to the bids across sample groups.

Sample group	Response to bids		χ^2statistic	p-value
	No	Yes		
WTP without policy consequentiality	48.45% [N = 266]	51.55% [N = 283]	0.009	0.93
WTP policy consequentiality	48.73% [N = 269]	51.27% [N = 283]		
WTA without policy consequentiality	48.99% [N = 266]	51.01% [N = 277]	0.001	0.97
WTA with policy consequentiality	48.89% [N = 264]	51.11% [N = 276]		

Note: The five bids (5, 10, 20, 50, and 100 birr) were randomly assigned in each sample group.

Table A.5), and a chi-squared test indicates that the distribution of the yes-no share is not significantly different across the policy consequentiality groups, in either the WTP and WTA samples.[12] This suggests that respondents did not need the additional verbal emphasis in the CV script of the policy importance of the survey, perhaps because the survey was initially presented, at the time of consent, as one conducted in collaboration with the Ethiopian Electric Utility. It may also reflect that respondents found the scenario to be realistic and not overly hypothetical, which is the key issue that the policy consequentiality treatment tries to address (Carson and Groves, 2007).

Table 6 further presents the percentage of 'yes' responses to the different bids across sample groups. The percentage of 'yes' responses declines with the amount of bid for the sample in the WTP but increases in the WTA framing, as would be expected. A comparison of these percentages within each policy consequentiality group suggests that there is no clear difference; the only exceptions to this are in the percentage who said yes to the WTA bid levels of 5 birr and 100 birr in the policy consequentiality group (34 and 77%, respectively) compared to those without policy consequentiality (49 and 63%, respectively).

Table 7 presents the probit estimates of the effects of policy consequentiality and the bid levels in the WTP and WTA sub-samples, with and without controls. As shown, the policy consequentiality treatment

[12] The only statistically significant difference between these randomly assigned groups is for the variable 'above high school education' where there is a weakly significant (at 10% level of significance) difference between those receiving the WTA with policy consequentiality script, and those not receiving it.

Table 6
Percentage of respondents who said yes to bids across sample groups.

		Bids (in birr)					Obs.
		5	10	20	50	100	
Percent of Yes Responses	WTP with policy consequentiality	77.2	74.3	53.2	33.9	21.9	553
	WTP without policy consequentiality	78.1	74.1	53.7	30.6	23.3	549
	WTA with policy consequentiality	33.6	46.5	47.0	51.8	76.6	540
	WTA without policy consequentiality	49.0	44.1	48.1	50.9	63.3	544

Table 7
Probit estimates of WTP and WTA (with and without controls).

Variables	WTP		WTA	
	(1)	(2)	(3)	(4)
Bid amount in birr	−0.016***	−0.017***	0.007***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)
Policy consequentiality	−0.004	−0.035	0.005	0.045
	(0.080)	(0.088)	(0.077)	(0.084)
Respondent is male		−0.265**		−0.131
		(0.125)		(0.112)
Age of respondent (years)		−0.002		0.000
		(0.003)		(0.003)
Respondent: Primary educ		0.367***		0.077
		(0.133)		(0.126)
Respondent: High school educ		0.246		0.085
		(0.152)		(0.147)
Respondent: > High school educ		0.529***		−0.156
		(0.167)		(0.152)
Married		0.258**		0.151
		(0.121)		(0.110)
log(household monthly expenditures)		0.217***		−0.070
		(0.068)		(0.062)
Addis Ababa		−0.011		−0.155
		(0.095)		(0.094)
Prepaid electric meter		−0.172		0.095
		(0.108)		(0.109)
log(hours of duration of outages in a typical month)		−0.143***		−0.182***
		(0.040)		(0.039)
Constant	0.620***	−0.808	−0.240***	0.882
	(0.071)	(0.620)	(0.068)	(0.578)
Log-likelihood	−667.7	−546.9	−729.3	−614.4
Observations	1101	951	1083	939
Mean WTP/WTA	39.6	39.9	33.3	42.3
Confidence interval	[32.5,46.7]	[34.6,45.3]	[18.6,48.1]	[31.4,54.2]

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

did not appear to substantially change responses. Respondents react to the bid levels in an expected way. Specifically, in the WTP framing, as the payment for reduced outages increases, the propensity to agree to the improvement scenario decreases. Conversely, in the WTA framing, respondents are more likely to agree to increased outages as the compensation amount increases. Table 7 also presents the WTP and WTA estimates derived from each model. Household WTP for a 3-h reduction in the duration of power outages is approximately 40 birr (US$1.4) across specifications, while WTA lies between 33 and 42 birr (US$1.1–1.4). These estimated values are equivalent to nearly 13%–16% of the average monthly electricity bill of 257 birr (US$8.9). Though WTA is often believed to exceed WTP for a variety of reasons (e.g., income effects, status quo bias, and loss aversion), as summarized by (Hanemann, 1991), in our case, the WTA measure may also include an element of altruism. This is because respondents may have accepted relatively lower compensation for increased outages, due to our explanation in the survey that increased outages could help to make electricity more available for people in rural areas.

Regarding the covariates in Columns 2 and 4 of Table 7, we observe stronger correlations with WTP than WTA, particularly for socio-economic characteristics such as education and expenditures, which are positively associated with willingness to accept a given bid. This is intuitive since WTP is constrained by income and resources, and more educated and higher-income respondents would thus be less constrained than those with fewer such resources. In both the WTA and WTP framings, respondents from households that experienced more or longer outages were less willing to pay or accept a given monetary amount; this may reflect the fact that such households have lower social status and are also unwilling to accept additional hardship, given their pre-existing high level of power disruptions.

The contingent valuation survey respondents were also asked follow-up debriefing questions. In response to a question about the degree of certainty respondents had when answering the valuation questions; 64% of the respondents were 'very certain', and 92% were either 'very certain' or 'certain'. Almost all of the remaining respondents were somewhat certain. Respondents who were not willing to pay the proposed price were asked whether they would be willing to pay if the cost of the additional hours of power supply were very low such as one birr. About 37% of those who responded were willing to pay such a very low price. Similarly, those who did not accept the proposed price were asked if they would change their mind if the compensation were as high as 100 birr. About 59% were willing to accept this proposed higher price. Taken together, this suggests that more respondents may have found reliability improvements to be unrealistic relative to compensation for outages (since many rejected even a very low cost for the former), and this may have actually suppressed our estimates of demand.

On the other hand, households who were not willing to pay or accept the proposed compensation for loss of power supply were asked to provide reasons for these negative responses. About 33% of those who responded reported high cost as the reason while about 14% noted that the proposed compensation was very small. About 17% of respondents said they did not have problems with power interruption and about 15% did not believe that the situation would actually improve. Besides, 26% of the respondents believe the responses of survey participants would be taken into consideration by the Ethiopian Electric Utility and related government institutions, whereas 46% believed that these would "somewhat considered". In response to a question on whether the respondent personally trusted the Ethiopian Electric Utility, about 53% trusted it somewhat and 14% trusted it completely.

In our final analysis, we consider whether energy poor households, as defined using the three different measures previously discussed were more or less likely to accept these bids, in both the WTP and WTA framings. Table 8 summarizes the basic results. We make several observations. First, results are largely consistent with those from the DCE, in that households classified as energy poor according to the fuels expenditure share measure have a higher demand for reliability improvements, in both WTA and WTP framings. In contrast, income poor households, and to a lesser extent households spending a greater amount on polluting fuels (only in the WTP framing), have somewhat lower demand for the improvements. Second, while the WTP and WTA measures are again largely overlapping, indicating no major divergence across the two, any apparent divergence appears greatest among the subgroup of energy poor. This may reflect the tighter budget constraints in those groups. The divergence is also most substantial when applying

Table 8
Probit estimates of WTP and WTA by energy poverty indicators.

Variables	Fuels poverty		Polluting fuels poverty		Income poverty	
	(1) Non poor	(2) Poor	(3) Non poor	(4) Poor	(5) Non poor	(6) Poor
Panel A: WTP						
Bid amount (birr)	−0.018***	−0.015***	−0.017***	−0.017***	−0.014***	−0.018***
	(0.002)	(0.004)	(0.001)	(0.003)	(0.002)	(0.002)
Log-likelihood	−411.1	−60.5	−497.2	−46.6	−169.5	−366.9
Observations	726	115	870	81	295	656
Controls	YES	YES	YES	YES	YES	YES
Mean WTP	36.5	56.7	40.0	35.6	56.4	38.7
Confidence interval	[30.7,42.4]	[34.9,93.8]	[34.6,45.7]	[11.6,57.8]	[40.4,76.4]	[32.2,45.5]
Panel B: WTA						
Bid amount (birr)	0.007***	0.009***	0.007***	0.014***	0.008***	0.008***
	(0.001)	(0.003)	(0.001)	(0.005)	(0.002)	(0.001)
Log-likelihood	−451.2	−81.9	−563.5	−44.3	−165.4	−442.9
Observations	695	134	858	81	268	671
Controls	YES	YES	YES	YES	YES	YES
Mean WTA	45.0	90.5	41.4	41.2	52.8	39.6
Confidence interval	[31.7,61.0]	[52.5203.4]	[29.3,54.6]	[16.5,87.9]	[21.9,95.8]	[25.6,55.0]

Note: Controls are those included in Table 7. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

the electricity poverty definition. As we have discussed, such households place a high value on electricity and may not be income poor, but the fact that they are already spending large amounts on electricity may more significantly constrain their WTP for improvements, compared to the minimum compensation they would require to allow more outages.

4. Conclusion

This paper examined households' valuation of power outages in 42 cities of Ethiopia using both discrete choice experiment (DCE) and contingent valuation (CV) methods. The DCE was used to estimate marginal willingness to pay for four attributes of outages: frequency of power outages, duration of power outages, time of a day that power outages occur, and notification of power outages. The CV method was then used to estimate willingness to pay (WTP) for a specific reduction in duration of power outages in the evening (by 3 h over the coming week), and willingness to accept (WTA) compensation for the corresponding increase in duration of power outages.

Our mixed logit models for the DCE show that attributes in the DCE were generally statistically significant and had the expected signs, except the duration attribute, which is not a statistically significant determinant of household choices. However, for many respondents, this attribute may have been deemed similar (but less salient) than the frequency of interruption attribute; that is, the standard deviation on the duration attribute is significant, suggesting that some households responded more strongly to it. The marginal willingness to pay for the most salient attributes of outages indicate that households, on average, are WTP about 11 birr (US$0.40) for a reduction in frequency of one outage per month, and 53 birr (US$1.80) per month to avoid daytime or evening outages, relative to morning outages. We also find that households prefer day-ahead outage notification to a week-ahead notification, with a marginal willingness to pay of 23 birr (US$0.79) per month. In the CV experiment, meanwhile, we find consistency across the WTP and WTA measures with demand for 3 fewer evening outage hours of 33–42 birr (US$1.1–1.4). This is equivalent to approximately 13% –16% of the average monthly electricity bill of 257 birr (US$8.9) and 33–44 times the average electricity tariff of 1 birr/kWh (3 US cents/kWh). This WTP would be comparable to the marginal WTP for fewer hours of outages in the DCE. Given that the DCE could have been for any outage, and not necessarily an evening outage that would be especially valuable, these estimates may not be fully consistent.

In the CV experiment, we also find that a policy consequentiality treatment does not affect stated demand. This is perhaps because the survey was initially introduced to respondents as being meant to inform Ethiopian Electric Utility policies and decisions. Regarding the similarity in the WTP and WTA estimates, it may derive from a few important features of the survey. First, it likely indicates that our survey did not induce substantial hypothetical bias, which can often lead to especially inflated estimates of WTA. Second, a change in the duration of outages by 3 h in a week would not appear to have large income effects, since such effects could lead to suppressed WTP relative to WTA. Finally, it suggests that there was not a great deal of altruism among respondents regarding better electricity services for rural households in exchange for more experienced outages, since this also would have led to divergence across the two measures (since there is no direct altruism mechanism in the WTP case). These various conclusions are of course speculative but plausible.

Overall, we observed considerable heterogeneity in sample households' preferences. In the DCE, this heterogeneity is not particularly strongly related to observable characteristics, except in responses to the cost (payment) attribute. Our examination of demand responses among groups classified as energy poor or non-poor indicated a set of interesting and intuitive patterns. First, it is worth emphasizing that the energy poor and non-poor are found to be different on a wide range of characteristics, but not in their exposure to outages (as measured by reported frequency and duration of power outages in the month prior to the survey). Still, households spending a large proportion of their income on electricity placed especially high value on reduced outages, in both the CV and DCE exercises. Yet we did find evidence of a divergence between WTP and WTA (with WTA being almost 50% higher) in that particular group, which may be particularly income constrained with respect to additional payments for electricity. On the other hand, households classified as energy poor according to income poverty and spending large amounts on alternative polluting fuels had lower demand for reduced outages than those classified as non-poor by the same measures. These energy poverty relationships point to a need to continue to carefully consider and find ways to confront the circular relationship between energy poverty and energy demand, if the objective of SDG 7, "access to affordable, reliable, sustainable and modern energy for all" is to be achieved.

These complexities notwithstanding, our results do point to several policy suggestions. First, households generally strongly value greater electricity reliability; policy-makers should therefore work to allow utilities to raise rates when they invest in such improvements, to break the low equilibrium trap of low tariffs and cost recovery that prevents needed maintenance and reliability-driven upgrades to generation capacity and transmission infrastructure. In Ethiopia, tariff reform is in fact already underway, with a phased approach of annual rate increases.

Policymakers must ensure that appropriate investments in improved service quality accompany these changes. Second, there is a continued need to identify better ways to target pro-poor electricity subsidies, given the lower demand and affordability challenge facing this group. In prior work, researchers have found that electricity subsidies in Ethiopia are largely regressive, with their benefits largely flowing to wealthier households who are more likely to have private, unshared connections and who do not consume much more electricity per connection, and because tariffs are uniformly too low (Cardenas and Whittington, 2019).

Credit author statement

Tensay Hadush Meles: conceptualization, study design, funding acquisition, methodology, data curation, writing–original draft preparation, and revising the manuscript.

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Declaration of Competing Interest

None.

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Appendix A. Additional Tables

Table A.1
List of sample cities and corresponding sample and population sizes.

Name of sample cities	Sample size	Population size	Name of sample cities	Sample size	Population size
Amhara regional state:			Oromia regional state:		
Ambasel	12	5582	Ambo	12	48,171
Bahirdar	48	155,428	Asela	12	67,269
Bati	12	16,710	Debrezeit	24	99,928
Debre Markos	12	62,497	Hurumu	12	4519
Debrebrehan	37	65,231	Jimma	36	120,960
Debretabor	12	55,596	Metu	11	28,782
Dessie	36	120,095	Nazareth	48	220,212
Efratana Gidim	12	15,319	Negele	12	35,264
Gondar	36	207,044	Nekemte	50	75,219
Kombolcha	12	58,667	Shashamane	47	100,454
Libokemkem	11	22,054	Weliso	12	37,878
Sekela	12	6679	Total	276	838,656
Total	252	790,902			
			SNNPR regional state:		
Tigray regional state:			Arba Minch	36	74,879
Adigrat	12	57,572	Dila	36	59,150
Adwa	12	40,502	Hawassa	36	157,139
Alamata	12	33,198	Hosaena	24	69,995
Mekelle	36	215,546	Loma	12	39,99
Saesi Tsadamba	12	18,839	Sodo	36	76,050
Tahitay Maychew	12	11,254	Timbaro	12	7615
Total	96	376,911	Welkite	12	28,866
			Total	204	477,693
Afar regional state:					
Asaita	48	16,052	Dire Dawa city admin.	71	233,224
Somali regional state:					
Jigjiga	24	125,876	Addis Ababa city admin.	1182	2,739,551
Harari regional state:					
Harar	36	99,368			

Note that the population size is based on the 2007 Ethiopian national population and housing census that is used in the sample frame for this study.

Table A.2
Summary statistics by energy poverty group.

		Fuels poverty			Polluting fuels poverty		Income poverty			
Variables	Obs.	Non-poor	Poor	P-value	Non-poor	Poor	P-value	Non-poor	Poor	P-value
Respondent characteristics:										
Male	2184	0.58	0.54	0.15	0.59	0.58	0.75	0.61	0.58	0.23
Age in years	2184	51.16	52.74	0.10	49.9	49.9	0.99	46.5	51.3	<0.001
Not literate	2184	0.18	0.21	0.16	0.18	0.18	0.85	0.12	0.21	<0.001
Primary education only	2184	0.36	0.39	0.44	0.37	0.35	0.67	0.26	0.42	<0.001
High school education	2184	0.24	0.25	0.64	0.24	0.20	0.16	0.27	0.23	0.057
More than high school education	2184	0.23	0.15	0.002	0.20	0.27	0.057	0.34	0.15	<0.001
Married	2184	0.59	0.57	0.48	0.59	0.58	0.80	0.56	0.61	0.033
Household characteristics:										
Household monthly expenditures (birr)	2184	7672	3984	<0.001	6929	6549	0.42	12,051	4642	<0.001
Household size	2184	4.80	4.49	0.02	4.61	4.59	0.94	3.74	4.98	<0.001
Owns home	2184	0.60	0.60	0.82	0.56	0.55	0.98	0.57	0.55	0.37
Region is Addis Ababa	2184	0.58	0.69	<0.001	0.54	0.57	0.44	0.54	0.54	0.91
Has no electric meter	2184	0.04	0.01	0.005	0.10	0.029	<0.001	0.11	0.09	0.15
Prepaid electric meter	1975	0.32	0.21	<0.001	0.26	0.38	0.002	0.35	0.24	<0.001
Postpaid electric meter	1975	0.68	0.79	<0.001	0.74	0.62	0.002	0.65	0.76	<0.001
Shared electric meter	1975	0.31	0.46	<0.001	0.41	0.33	0.040	0.44	0.39	0.038
Monthly electricity bill in Birr (reported for last month)	1811	198.67	597.35	<0.001	266.5	172.8	<0.001	296.8	240.6	<0.001
Frequency of outages in a typical month	2152	18.03	17.57	0.74	18.3	16.6	0.228	17.9	18.3	0.68
Total duration of hours of outages in a typical month	2152	49.80	48.78	0.79	51.6	44.1	0.111	52.2	50.4	0.57
Has a backup source during outages	2184	0.03	0.06	0.04	0.029	0.017	0.245	0.045	0.021	<0.007

Table A.3
Conditional logit estimates with interactions.

Variables	(1) Male Respondent	(2) Age > average	(3) Education ≥ high school	(4) Household size > average	(5) Addis Ababa	(6) Household expenditure > average	(7) Prepaid meter
Increase in monthly bill	−0.001***	−0.002***	−0.002***	−0.002***	−0.002***	−0.002***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Frequency	−0.071***	−0.067***	−0.068***	−0.071***	−0.053***	−0.061***	−0.059***
	(0.010)	(0.010)	(0.007)	(0.009)	(0.010)	(0.008)	(0.008)
Duration	0.048***	0.038***	0.029***	0.030**	0.034**	0.026**	0.027**
	(0.016)	(0.014)	(0.011)	(0.014)	(0.016)	(0.012)	(0.012)
Evening (=1 if outage occurs in evening)	0.018	0.022	0.023	−0.042	0.042	−0.015	0.035
	(0.050)	(0.046)	(0.036)	(0.046)	(0.050)	(0.039)	(0.039)
Morning (=1 if outage occurs in morning)	0.295***	0.232***	0.276***	0.239***	0.297***	0.192***	0.310***
	(0.049)	(0.046)	(0.036)	(0.045)	(0.049)	(0.039)	(0.038)
Week notice (=1 if a week prior notification about outages)	−0.056	−0.052	−0.040	−0.045	−0.050	−0.052*	−0.024
	(0.036)	(0.034)	(0.027)	(0.034)	(0.037)	(0.029)	(0.029)
ASC (=1 if status quo)	0.009	−0.283***	−0.020	−0.030	−0.201**	−0.120*	−0.075
	(0.081)	(0.077)	(0.060)	(0.076)	(0.082)	(0.065)	(0.064)
Increase in monthly bill*Characteristic	−0.001***	0.000	−0.000	−0.000	0.000	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Frequency*Characteristic	0.004	−0.003	−0.005	0.004	−0.026*	−0.023*	−0.032
	(0.013)	(0.013)	(0.016)	(0.013)	(0.013)	(0.014)	(0.015)
Duration*Characteristic	−0.025	−0.011	0.015	0.004	−0.002	0.015	0.003
	(0.020)	(0.020)	(0.024)	(0.020)	(0.020)	(0.021)	(0.022)
Evening*Characteristic	−0.022	−0.034	−0.082	0.090	−0.063	0.058	−0.106
	(0.065)	(0.064)	(0.076)	(0.064)	(0.065)	(0.067)	(0.071)
Morning*Characteristic	−0.087	0.020	−0.149**	0.008	−0.092	0.151**	−0.251***
	(0.063)	(0.063)	(0.075)	(0.063)	(0.064)	(0.066)	(0.070)
Week notice*Characteristic	0.023	0.020	−0.008	0.007	0.015	0.032	−0.057
	(0.048)	(0.047)	(0.056)	(0.047)	(0.048)	(0.049)	(0.053)
ASC*Characteristic	−0.240**	0.284***	−0.559***	−0.200*	−0.124	−0.136	0.012
	(0.107)	(0.106)	(0.128)	(0.105)	(0.107)	(0.112)	(0.118)
Log-likelihood	−11,617	−11,616	−11,595	−11,617	−11,626	−11,557	−11,221
Observations	32,598	32,598	32,598	32,598	32,598	32,598	30,726

Note: We estimate the interaction of the household socio-demographic variables with all the attributes but reported the statistically significant coefficients. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.4
Conditional logit model estimates with interaction terms for quartile of energy poverty measure distributions.

	fuel share of spending	Polluting fuel expenditure	Per capita expenditure
Variables	(1)	(2)	(3)
Increase in monthly electricity bill	−0.001	−0.002***	−0.001
	(0.001)	(0.000)	(0.001)
Frequency of outages	−0.073***	−0.069***	−0.056***
	(0.012)	(0.007)	(0.013)
Duration of outages	0.002	0.037***	0.026
	(0.018)	(0.010)	(0.020)
Evening outages	−0.072	−0.008	0.019
(reference: a daytime or nighttime outage)	(0.060)	(0.033)	(0.055)
Morning outages	0.241***	0.230***	0.130*
(reference: a daytime or nighttime outage)	(0.066)	(0.036)	(0.068)
A week prior outage notification	−0.023	−0.046**	−0.030
(reference: a day prior outage notification)	(0.039)	(0.023)	(0.039)
ASC (=1 if status quo)	−0.020	−0.140*	0.230
	(0.139)	(0.080)	(0.159)
Interaction terms: (reference: 1st quarter)			
Increase in electricity bill * 1 if 2nd quarter	−0.004***		−0.001
	(0.001)		(0.001)
Increase in electricity bill * 1 if 3rd quarter	−0.002**		−0.000
	(0.001)		(0.001)
Increase in electricity bill * 1 if 4th quarter	−0.000	0.000	−0.000
	(0.001)	(0.000)	(0.001)
Frequency of outages * 1 if 2nd quarter	0.017		−0.016
	(0.017)		(0.017)
Frequency of outages * 1 if 3rd quarter	−0.000		−0.007
	(0.017)		(0.018)
Frequency of outages * 1 if 4th quarter	−0.000	0.000	−0.026
	(0.017)	(0.018)	(0.018)
Duration of outages * 1 if 2nd quarter	0.066***		−0.003
	(0.025)		(0.027)
Duration of outages * 1 if 3rd quarter	0.068***		0.014
	(0.025)		(0.027)
Duration of outages * 1 if 4th quarter	−0.021	−0.026	0.013
	(0.026)	(0.025)	(0.027)
Evening outages * 1 if 2nd quarter	0.151*		−0.095
	(0.085)		(0.081)
Evening outages * 1 if 3rd quarter	0.079		0.046
	(0.084)		(0.079)
Evening outages * 1 if 4th quarter	0.072	0.075	−0.007
	(0.084)	(0.087)	(0.084)
Morning outages * 1 if 2nd quarter	0.098		0.114
	(0.098)		(0.095)
Morning outages * 1 if 3rd quarter	0.004		0.121
	(0.095)		(0.093)
Morning outages * 1 if 4th quarter	−0.087	0.080	0.207**
	(0.097)	(0.091)	(0.096)
A week notification * 1 if 2nd quarter	−0.054		−0.029
	(0.057)		(0.054)
A week notification * 1 if 3rd quarter	−0.038		0.001
	(0.058)		(0.051)
A week notification * 1 if 4th quarter	0.022	0.027	−0.020
	(0.057)	(0.076)	(0.056)
ASC* 1 if 2nd quarter	−0.449**		−0.442**
	(0.204)		(0.226)
ASC* 1 if 3rd quarter	−0.376*		−0.625***
	(0.201)		(0.218)
ASC* 1 if 4th quarter	0.238	0.072	−0.511**
	(0.211)	(0.161)	(0.217)
Observations	32,598	32,598	32,598
Log-likelihood	−11,572	−11,627	−11,540

Notes: The quartile distributions of the ratio of fuels expenses to household expenditures are: less than 1.6% (1st quartile), 1.6%–3.2% (2nd quartile), 3.2%–6% (3rd quartile), and greater than 6% (4th quartile). For polluting fuels poverty, there are only two groups, as 83.4% of the sample do not report spending money on polluting fuels. Finally, the quartile distributions of the household monthly expenditure per capita (a proxy measure of income per capita) are less than 816 birr (1st quartile), 816–1217 birr (2nd quartile), 1217–1871 birr (3rd quartile), and greater than 1871 birr (4th quartile). Robust standard errors clustered at the respondent level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.5
Balance tests: WTP and WTA with or without policy consequentiality.

Variables	WTP with or without policy consequentiality			WTA with or without policy consequentiality		
	With	Without	Diff	With	Without	Diff
Respondent's characteristics:						
Male	0.596	0.603	0.0067	0.583	0.571	−0.012
	(0.491)	(0.49)	(0.23)	(0.493)	(0.495)	(−0.41)
Age in years	49.755	49.714	−0.041	49.956	50.09	0.135
	(13.822)	(15.033)	(−0.05)	(15.243)	(15.885)	(0.14)
No literacy	0.178	0.199	0.021	0.169	0.184	0.016
	(0.382)	(0.399)	(0.89)	(0.375)	(0.388)	(0.675)
Primary education	0.339	0.368	0.029	0.381	0.389	0.007
	(0.474)	(0.483)	(1.01)	(0.486)	(0.488)	(0.24)
High school education	0.261	0.242	−0.019	0.22	0.239	0.019
	(0.44)	(0.429)	(−0.71)	(0.415)	(0.427)	(0.74)
Above high school	0.223	0.191	−0.032	0.23	0.188	−0.042*
	(0.417)	(0.394)	(−1.29)	(0.421)	(0.391)	(−1.693)
Married	0.601	0.59	−0.011	0.607	0.569	−0.038
	(0.49)	(0.492)	(−0.38)	(0.489)	(0.496)	(−1.28)
Household monthly expenditures (in birr)	7196.08	6627.28	−568.8	6630.52	7135.43	504.9
	(12047)	(6463.5)	(−0.98)	(5887.8)	(11,866)	(0.89)
Household size	4.556	4.617	0.061	4.702	4.549	−0.153
	(2.041)	(2.02)	(0.50)	(2.005)	(2.062)	(−1.24)
Lives in own home	0.576	0.543	−0.033	0.57	0.532	−0.038
	(0.495)	(0.499)	(−1.11)	(0.495)	(0.499)	(−1.26)
City is Addis Ababa	0.543	0.541	−0.002	0.531	0.536	0.004
	(0.499)	(0.499)	(−0.08)	(0.499)	(0.499)	(0.15)
No electric meter	0.188	0.173	−0.015	0.185	0.193	0.008
	(0.391)	(0.379)	(−0.66)	(0.389)	(0.395)	(0.34)
Prepaid electric meter	0.304	0.346	0.042	0.289	0.279	−0.01
	(0.46)	(0.476)	(1.35)	(0.454)	(0.449)	(−0.33)
Postpaid electric meter	0.696	0.654	−0.042	0.711	0.721	0.010
	(0.469	(0.476)	(−1.35)	(0.454)	(0.449)	(0.33)
Shared electric meter	0.397	0.376	−0.020	0.438	0.391	−0.047
	(0.499	(0.485)	(−0.66)	(0.497)	(0.488)	(−1.50)
Monthly electricity bill in birr (reported for last month)	235.12	255.144	19.98	264.12	276.09	11.96
	(247.64)	(335.38)	(1.03)	(276.80)	(425.60)	(0.50)
Frequency outages in a typical month	17.794	19.808	2.014	17.52	17.44	−0.087
	(20.155)	(25.955)	(1.43)	(18.78)	(18.30)	(−0.08)
Total duration hours of outages in a typical month	52.081	52.615	0.534	51.41	47.68	−3.73
	(68.069)	(68.824)	(0.13)	(59.93)	(59.99)	(−1.01)
Household has a backup source during outages	0.029	0.024	−0.005	0.033	0.028	−0.006
	(0.168)	(0.152)	(−0.55)	(0.18)	(0.164)	(−0.55)
Number of respondents	522	549	1101	540	543	1083

Note: Standard deviations are in parentheses for the average values. For the difference, t statistics are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.6
Summary of the estimated values from DCE and CV methods as a share of the average monthly electricity bill.

Variables	Estimated value	Share of average monthly bill (257 birr ≈ US$8.86)
Marginal WTP for (DCE):		
A unit reduction in the number of outages per month (frequency of outages)	11 birr (US$0.38)	4.3%
Morning outages compared to daytime or night-time outages	53 birr (US$1.83)	20.6%
A day prior notification compared to a week prior outage notification	23 birr (US$0.79)	8.9%
WTP/WTA from CV methods:		
WTP for 3 h evening outages reduction	40 birr (US$1.38)	15.6%
WTA for 3 h evening outages	42 birr (US$1.44)	16.3%

Note that we reported here the marginal WTP estimates for the statistically significant attributes in the DCE. Also, the reported WTP/WTA estimates from the CV methods are the specifications with additional control variables.

Appendix B. Stated preferences scenarios

Annex 1. Discrete Choice Experiment.

As you might know, there are power outage problems in Ethiopia. Currently, it is mainly caused by limited power generation, poor power distribution and transmission systems due to old age of the systems and limited capacity of the systems relative to increasing demand. Addressing the problem requires investment to increase power generation capacity and to improve the power distribution and transmission systems. Such investment is expected to reduce the frequency and duration of power outages. The investment can also be used to cover costs of notifying customers when there are power outages so that customers can take necessary measures. We have identified the following four characteristics associated with power outages and would like to ask you about your preferences regarding these characteristics. The characteristics identified are: duration of power outages, frequency of power outages, time of a day when outages occur and whether or not there will be notification of customers about power outages. The government does not have the resources to cover the costs and the contribution of the customers will be the source of funds for the investment. So, we also include an increase in monthly electricity bill as one of the characteristics as the cost of improvements should be covered through this.

Alternatives are presented to you including the existing situation and you will be asked to choose from these alternatives. We will change the combination of levels of the characteristics and ask you to choose from the alternatives repeatedly.

Please note that the choice you make only affects the attributes identified and everything else remains as it is today. Note also that money obtained from the tariff increase is used solely to improve the electricity service by the government. Also remember that when you pay for the improvements in electricity service, it means the money will not be available to pay for other purposes.

In previous studies that are similar to this, some respondents state their unwillingness to pay for improvement in electricity service not because they do not want improvements, but for other reasons. These reasons include the belief that respondents have the right to uninterrupted electricity supply and that the money collected would not be used for the intended purposes. When choosing from the alternatives, we kindly request you not to think this way. But you might have other reasons for unwillingness to pay and we would also like you to tell us such reasons following your choices. For example, perhaps the cost is simply too high for you in comparison with the benefits that you would receive from more reliable electricity. Or maybe you simply cannot afford the additional expense. Consider especially the other needs that your household has, that themselves cost money, and would need to be reduced if you had to devote more money to your electricity bill.

Please also note that proposed improvements will be implemented if these are supported by the majority of respondents; otherwise they will not be implemented.

We will start with an example to see if you understand the questions before we proceed to the series of questions that we will ask you. You will be asked to choose from three options (one of these is the existing situation while the other two are alternatives for improvement in electricity service).

An example of a choice set

Attributes	Status quo	Alternative 1	Alternative 2
Duration of power outages in hours	5 h	1 h	4 h
Frequency of power outages per month	8 times	Once	Six times
Time of a day when outages occur	Any time	06:00p.m to 10: 00p.m (evening –peak load)	9:00a.m to 6:00 pm and10: 00p.m to 05: 00a.m (outside morning and evening)
Notification of customers about a power outage	No notification	A day prior notification	A week prior notification
Increase in monthly electricity bill	No increase in your electricity bill	100% increase in your electricity bill	25% increase in your electricity bill
Respondent's preferred choice	◯	◯	◯

Enumerator: Please explain to the respondent the three alternatives (including the status quo) and then ask for the option that the respondent chooses. If the respondent does not understand, please explain repeatedly and also respond to any questions from the respondent.

Annex 2. Contingent Valuation

A. WTP with policy consequentiality

Now we would like to ask you about your willingness to pay for a reduction in power outages in particular.

Please note that the survey is conducted in partnership with Ethiopian Electric Utility (EEU).

Enumerator: Please show a formal letter to the respondent signed by the Ethiopian Electric Utility which indicates that “the EEU will consider the results of the study in decisions regarding electricity service improvement”. In cases where the respondent is illiterate please read the contents of the letter to the respondent.

As you might know, there are power outage problems in Ethiopia. Currently, it is mainly caused by limited power generation, poor power distribution and transmission systems due to an old age of the systems and limited capacity of the systems relative to increasing demand. Addressing the problem requires investment to increase power generation capacity and to improve the power distribution and transmission systems. Such investment is expected to reduce the duration of power outages. The investment can also be used to cover costs of notifying customers when there are power outages so that customers can take necessary measures.

As you might know millions of people in rural Ethiopia do not have access to electricity and some who have access can use electricity only for very limited hours a day. This is because a number of rural villages are not connected to power supply from the grid at all and some of those that are connected face serious power outage problems. Improvements in power supply with investments made using contributions of people like you would also help improve access to electricity for rural people.

The government does not have the resources to cover the costs of reducing the duration of power outages and the cost of notifying customers when there are power outages. The contribution of the customers will be the source of funds to cover these costs. So, people are expected to pay for the reduction in the duration of power outages and the payment is in the form of an increase in monthly electricity bill.

In previous studies that are similar to this, some respondents state their unwillingness to pay for improvement in electricity service not because they do not want improvements, but for other reasons. These reasons include the belief that respondents have the right to uninterrupted electricity supply and that the money collected would not be used for the intended purposes. When choosing from the alternatives, we kindly request you not to think that this will not happen. But you might have other reasons for unwillingness to pay and we would also like you to tell us such reasons following your choices. For example, perhaps the cost is simply too high for you in comparison with the benefits that you would receive from more reliable electricity. Or maybe you simply cannot afford the additional expense. Consider especially the other needs that your household has, that themselves cost money, and would need to be reduced if you had to devote more money to your power bill.

Please also note that proposed improvements will be implemented if these are supported by the majority of respondents; otherwise, they will not be implemented.

So, imagine you have been asked to pay money to get 3 h of power supply any time between 6 pm and 10 pm in the evening next week on top of the typical number of hours electricity is available to you. This can be implemented using pay as you go systems with special meters that allow monitoring of consumption this way. (Enumerator: please show pictures of such meters and systems). You would make the payment once to the EEU with your bill next month.

You should also know that even though this is a survey, the EEU is considering implementing an intervention that would allow this type of electricity payment. So, if you would honestly be WTP and say that you would not, the utility may decide that too few people are interested to warrant the investment. On the other hand, if you answer that you are willing to pay but really are not, the EEU may devote resources to this, rather than to other projects that would also deliver electricity benefits to the population.

Would you pay _____ birr to have power for 3 h any time between 6 pm and 10 pm in one evening next week?

1. Yes 2. No

B. WTA with policy consequentiality

Now we would like to ask you about your willingness to accept compensation for power outages in particular.

Please note that the survey is conducted in partnership with Ethiopian Electric Utility (EEU).

Enumerator: Please show a formal letter to the respondent signed by the Ethiopian Electric Utility which indicates that "the EEU will consider the results of the study in decisions regarding electricity service improvement". In cases where the respondent is illiterate please read the contents of the letter to the respondent.

As you might know millions of people in rural Ethiopia do not have access to electricity and some who have access can use electricity only for very limited hours a day. This is because a number of rural villages are not connected to power supply from the grid at all and some of those that are connected face serious power outage problems.

The government has very limited resources to cover the costs of improving access to electricity. One option that is being considered is for individuals/households like yours to be paid money so that they can give up some hours of power supply.

In previous studies that are similar to this, some respondents state their unwillingness to state their willingness to accept compensation for giving up some hours of power supply not because they do not want the compensation, but for other reasons. These reasons include the belief that the respondents will not be compensated for the power supply they give up. When choosing from the alternatives, we kindly request you not to think that this will not happen. But you might have other reasons for unwillingness to be compensated and we would also like you to tell us such reasons following your choices.

Please also note that proposed improvements will be implemented if these are supported by the majority of respondents; otherwise, they will not be implemented.

So, imagine you have been given an opportunity to be paid money to give up 3 h of power supply any time between 6 pm and 10 pm in the evening next week to increase access to electricity for other households in rural Ethiopia by 3 h on top of the typical number of hours electricity is available to them or to make electricity available to those who do not have access. This can be implemented using pay-as-you-go systems with special meters that allow monitoring of consumption this way. (Enumerator: please show pictures of such meters and systems).

You would know in advance that the outage will occur. You would receive the payment once next month from the EEU in the form of an equivalent reduction in your monthly bill.

You should also know that even though this is a survey, the EEU is considering implementing an intervention that would allow this type of arrangement. So if you would honestly be WTA and say that you are not, the utility may decide that too few people are interested to warrant the investment. On the other hand, if you answer that you are willing to accept but really are not, the EEU may devote resources to this, rather than to other projects that would also deliver electricity benefits to the population.

Would you accept ____ birr not to have power for 3 h any time between 6 pm and 10 pm in one evening next week?

1. Yes 2. No

Follow-up questions to all contingent valuation questions:

How certain was the respondent when answering the questions (1. very certain, 2. certain, 3. somewhat certain, 4. not certain at all) ___________________.

If not willing to pay the price, what if the cost of these additional hours of supply were very low (such as 1 ETB), would you still say no? 1. Yes; 2. No __________.

If not willing to accept the price, what if the compensation were really high (such as 50 ETB). Would you still not accept it? 1. Yes, 2. No ________.

For those who reject, why do they reject (both for WTP and WTA questions)? (1. May not trust the intervention, 2. may not like the idea of these meters that monitor consumption closely; 3. Other (specify)_________).

If you are not willing to pay for improvement in electricity service or not willing to accept compensation for loss of power supply, why is it so? (1. due to high cost, 2. Due to very small compensation; 3. due to lack of problems with interruptions,4. due to mistrust that the situation will actually improve, 5. Other(specify)_________.

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2021.105527.

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