Measuring willingness to pay for reliable electricity: Evidence from Senegal *

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June 30, 2020

Abstract

Low-quality electricity service constitutes a significant obstacle in achieving sustainable development. Governments in low-income countries and donors are increasingly seeking to invest in improving electricity service quality and reliability. Understanding households' and firms' willingness to pay (WTP) for quality improvements is key to designing investments in the electricity sector. In this paper, we provide new evidence on WTP for service quality improvements from a nationally-representative survey in Senegal. We find that households and firms are willing to pay a premium over current tariffs for high-quality electricity service without outages. However, WTP for marginal service improvements is significantly lower than WTP for uninterrupted service, suggesting that, for households and firms, any increase in electricity tariff must be accompanied by substantial quality improvements. We discuss the multi-round bidding game built in our data to emphasize the importance of design choices in eliciting the WTP and draw some policy implications.

Keywords: willingness to pay, contingent valuation, DCm, unique valuation assumption
JEL codes: L94, D46, L11, O13, Q41

*We would like to thank participants of the seminar series at the University of Groningen for their inputs. We are especially grateful for the comments provided by the Editor and three anonymous referees. We also express our gratitude to Francis Mulangu for leading the MCC's WTP survey and for facilitating the use of the data for research, as well as to the UFC-MCA team in Senegal. All errors and omissions are the sole responsibility of the authors.

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1 Introduction

Improving access to electricity is an essential component of long-term development in low-income countries. Electrification can raise female employment (Dinkelman, 2011; Grogan & Sadanand, 2013), increase industrialization (Rud, 2012), improve development and labor productivity (Lipscomb *et al.*, 2013), increase agricultural income (Chakravorty *et al.*, 2016), increase educational attainment (Litzow *et al.*, 2019), and reduce indoor air pollution (Barron & Torero, 2017).[1] Improved quality of service has a large impact on household incomes (Rao, 2013), perhaps larger than the impact of a low-quality grid connection (Chakravorty *et al.*, 2014). However, service quality remains a key policy challenge with recurrent outages and poor electricity infrastructure persisting in many countries.

Grid connections are one key component of improved electricity access. Experimental evidence suggests that demand for electricity access, via grid connection or solar technology, is significantly lower than the construction costs required to connect these households (Lee *et al.*, 2020; Grimm *et al.*, 2020; Sievert & Steinbuks, 2020). Peer effects may play a role in increasing household demand for grid connections (Bernard & Torero, 2015). Even if households do achieve grid access, impacts may be muted or accrue slowly if the use of electricity and uptake of appliances is low (Lenz *et al.*, 2017) or requires significant household investment (Richmond & Urpelainen, 2019).

Similarly, access to electricity may be of little value if the quality of service is low, making quality of service the second key component of improved electricity access. This may explain why the reliability of electricity service is an important driver of willingness to pay for access (Blimpo *et al.*, 2020; Kennedy *et al.*, 2019). Service quality appears to play a large role in determining whether households and firms can enjoy the benefits of electricity access (Blimpo & Cosgrove-Davies, 2019). Electricity outages and high tariffs have negative impacts on firm productivity (Abeberese, 2016; Allcott *et al.*, 2016; Hardy & McCasland, 2019) and reduce the share of small firms working in electricity-intensive sectors (Alby *et al.*, 2013). Government policies to maintain service for nonpaying households may create disincentives for service providers to increase the quality of electricity service (McRae, 2015).

Despite the obvious benefits of reliable electricity service, it remains scarce throughout

[1] Some recent evidence does suggest caution when expecting large employment or economic effects from rural electrification (Burlig & Preonas, 2016).

Sub-Saharan Africa (Blimpo & Cosgrove-Davies, 2019; Blimpo *et al.*, 2020), and substantial investments in infrastructure are needed to improve the quality of service. In this paper, we focus on the willingness to pay (WTP) for improved electricity service among households and firms in Senegal. With several notable exceptions (Yoon *et al.*, 2016; Burgess *et al.*, 2019; Lee *et al.*, 2020; Grimm *et al.*, 2020), researchers wishing to study the WTP for electricity access or service quality must typically rely on hypothetical elicitations and choice experiments. In this paper, we use a nationally-representative survey of already-connected households and firms in Senegal, which elicited WTP for high-quality service and marginal improvements in service quality using an iterative bid contingent valuation (CV) approach. CV methods are common in the literature studying access to electricity, with a variety of sub-national (Taale & Kyeremeh, 2016; Oseni, 2017) and national (Carlsson & Martinsson, 2007; Osiolo, 2017) surveys using CV methods that show positive and economically meaningful WTP for improved energy quality.[2] This iterative method involves offering respondents a sequence of prices that ascend or descend, depending on the first response.

CV methods can provide useful insights into the policy implications of WTP for quality electricity. Households with a high WTP for reliable electricity may engage in costly mitigation behaviors like investing in self-generation (Oseni, 2017). In some contexts, household WTP alone is high enough to justify investment in improved service quality (Gunatilake *et al.*, 2012). Households and firms are willing to pay more to avoid unplanned outages than planned outages of the same duration (Carlsson & Martinsson, 2007; Morrison & Nalder, 2009). Households may be willing to pay more for a reliable electricity grid connection compared with the use of renewable energy (Abdullah & Jeanty, 2011). Research using other types of choice experiments across a range of sub-national settings in middle and high-income countries also shows a positive willingness to pay to reduce the frequency and duration of power outages (Abdullah & Mariel, 2010; Pepermans, 2011; Hensher *et al.*, 2014; Ozbafli & Jenkins, 2015; Abrate *et al.*, 2016), particularly during the winter (Ozbafli & Jenkins, 2016; Morrissey *et al.*, 2018).

In Senegal, improving electricity service quality is a significant challenge. Electricity services in Senegal are beset by unreliability. In our samples, households and firms report a

[2] Contingent valuation is also common for eliciting WTP for other types of infrastructure, like domestic water (Whittington *et al.*, 1991; Altaf *et al.*, 1993; Kaliba *et al.*, 2003; Dutta & Tiwari, 2005; Adenike & Titus, 2009), sanitation and waste management (Whittington *et al.*, 1993; Anjum Altaf & Hughes, 1994; Rahji & Oloruntoba, 2009; Ezebilo, 2013; Acey *et al.*, 2019), health products (Prabhu, 2010), water quality (Choe *et al.*, 1996), and even for targeting conditional cash transfers (Alix-Garcia *et al.*, 2019).

mean 1.4 outages per week (median 1), lasting an average of 53 minutes (median 30) and 31 minutes (median 20), respectively. More than 75% of households and firms report at least one electricity interruption per week. 70% of firms report that power outages cause revenue losses.[3] Understanding the magnitude of households and firms' WTP for improved quality relative to increased investment requirements (as in Gunatilake *et al.* 2012) is one crucial step towards designing better public policy for the sector.

In this paper, we first provide a careful characterization of Senegalese households' and firms' WTP for high-quality electricity service using nationally-representative survey data. We show how WTP correlates with observable characteristics, and in particular, how it relates to existing tariffs. This heterogeneity may prove important in designing reforms in the electricity sector and making electricity distribution more efficient and sustainable.

Second, we demonstrate some potential pitfalls in estimating WTP using an iterative bid design. In particular, we show that the single valuation assumption may not be satisfied in the data, leading to a (downward) bias that is economically important. Third, we compare the estimated WTP for high-quality service with estimated WTP for marginal improvements in service quality. The gap in WTP between these two scenarios is economically meaningful and suggests caution for policymakers seeking to recover the costs of marginal quality improvements with tariff hikes.

The remainder of the paper is organized as follows. We first describe the dataset and present summary statistics in section 2. Then, we describe the analytical framework used for analyzing household and firm data in section 3. Section 4 presents the results of our analysis, and finally section 5 concludes.

2 Data and summary statistics

For this study, we use a nationally-representative survey dataset of households and firms collected between March and June 2018 (Almanzar & Ulimwengu, 2019).[4] The dataset includes detailed information on 2775 households and 1072 enterprises (206 formal and 866 informal) in all 14 regions of Senegal. Eighty-three percent of the surveyed households are

[3] Somewhat in contrast to Hardy & McCasland (2019), formal firms are slightly more likely to report revenue losses due to outages than informal firms, and similarly large formal firms more likely than small formal firms.

[4] This survey was implemented by SMJDATA as part of the preparatory studies for designing the Second Senegal Compact which comprises three main projects in the power sector (Access, Transmission and Institutional Reform.

connected to the electric grid, provided by either the state-run electricity utility (*SENELEC*) (92 percent) or a private dealer (8 percent). Ninety-six percent and sixty-six percent of formal and informal firms interviewed are respectively connected to the grid.

2.1 Household sample

Households were sampled using a three-stage stratified random sampling approach. Communes were first randomly selected from each region, with the number of households to survey in each region calculated based on the estimated population. Within each commune, enumeration areas used by the Senegalese National Statistical Institute (ANSD) were randomly selected, with the selection probability proportional to size. Finally, the survey team conducted a census within enumeration areas and selected a sample of 15-20 households from each area (Almanzar & Ulimwengu, 2019).

Of the 2775 households surveyed, 1827 males and 1793 females responded to the WTP modules, with 863 households having two respondents. Male respondents are older, more educated, more likely to be married, employed, literate in French, and more likely to report being the household head. See Table A.3 for more details on respondent-level demographics.

The sample also differs significantly along the urban-rural dimension. We find that urban households are significantly more likely to have a bank account, smaller in size, less likely to own their home, and more likely to be connected to the grid. Urban households also report significantly greater non-electricity energy expenses per month. See Table A.4 for more details on the urban-rural differences in the sample.

Due to the relatively small sample of unconnected households, we restrict our analysis in subsequent sections to only connected households. Nevertheless, it is instructive to compare connected and unconnected households on observable characteristics. In Table A.5, we show that unconnected households are significantly less likely to have a bank account, smaller in size, but they are not less likely to own a home. Unconnected households also report significantly lower non-electricity energy expenses per month. Ninety-four percent of unconnected households in the sample report that electricity is available in their area. Moreover, the median household reports being just 15 meters from the nearest electric pole (mean 188 meters). Therefore, in general, the fact that households are not currently connected is not entirely explained by a lack of electricity infrastructure. These results should caution the reader in generalizing estimated WTP for high-quality electricity, as households that are not currently connected may exhibit significantly lower willingness or ability to pay.

Among connected households, we find that only 21 percent rely exclusively on the electric grid for energy. The median connected household spends 41 percent of their estimated monthly energy expenditures (about $25) on energy sources other than electricity from the grid, suggesting that households would save more if they could rely more or exclusively on the grid. Thirty-five percent of households report being “unsatisfied” or “very unsatisfied” with the electricity services they currently receive. When asked under what conditions they would be willing to pay more for electricity services, households most commonly report 24/7 service (83 percent), no unexpected power outages (55 percent), improved service at night (48 percent), and improved service during the day (48 percent).

2.2 Enterprise sample

The firm sample includes both formal and informal firms. The firm survey used a stratified sampling approach based on the Senegal General Business Census of 2016 (Almanzar & Ulimwengu, 2019). In total, the dataset includes 538 informal firms and 188 formal firms. The vast majority of firms interviewed are located in Dakar, reflecting the highly concentrated nature of the Senegalese economy.

Table A.6 shows how firms differ by formality status. Informal firms are younger, more likely to be rural, report fewer employees, more likely to be a home-based business, and less likely to report an income loss from power outages. The primary respondent for informal firms is younger and less educated than the one for formal firms but is not more likely to be female. Finally, informal firms report paying a smaller tariff per kWh than formal firms.

2.3 Willingness to pay elicitation method

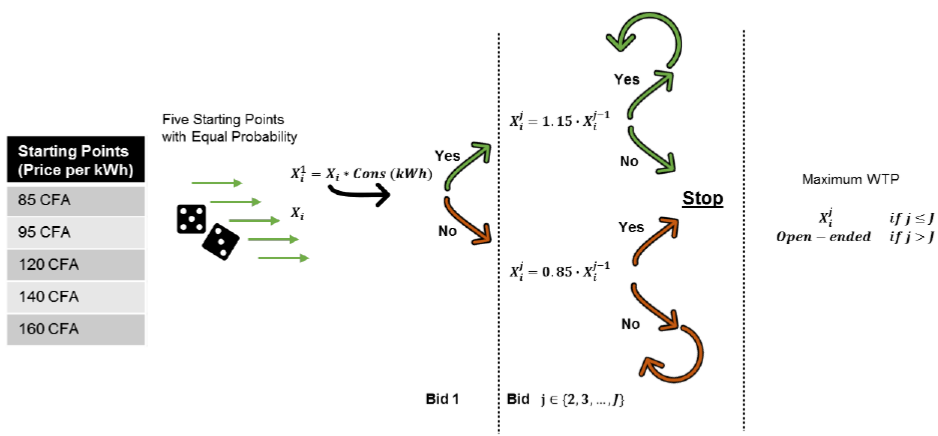
Willingness to pay was elicited using an iterative bid approach. Households and firms were asked to indicate their WTP for high-quality electricity service, without power cuts or voltage drops.[5] See Appendix C for more details about the exact wording of the questions. The bidding game followed an introduction in which respondents were reminded about their

[5]Note: throughout the paper, unless unless stated otherwise, we restrict our analysis to households and firms already connected to the grid. Sample size issues and possible protest bidding among unconnected respondents, as well as a different question formulation, limit the usefulness of WTP estimates for unconnected households and firms in our data.

current expenses on electricity and that their answers could be used to design policy in the future, as a reminder to attempt to answer truthfully, although this does not eliminate the potential for bias from protest bids or strategic misreporting.[6]

Respondents were first asked whether they would accept to pay one of five randomly-drawn prices per kWh of electricity.[7] These values were selected to roughly cover the range of possible prices currently charged by SENELEC. The respondents were also given in each case the equivalent monthly bill amount based on their current electricity usage and the hypothetical price. If the respondent answered "yes" ("no") to the first question, amounts associated with subsequent questions would increase (decrease) from the starting value. For all questions following the first, the amount offered was 115% (85%) of the previous value. The questions continued until the respondent changed their response (from "yes" to "no" or vice versa), to a maximum of 12 possible values offered. If the respondent maintained the same response for all 12 questions, he/she would be asked an open-ended question about their WTP.

Figure 1: Willingness to Pay elicitation method



Source: Almanzar & Ulimwengu (2019)

The median household respondent answered only four rounds of the WTP survey before changing their response, and 82% responded to less than six rounds. Figure 2 shows the distribution of the number of rounds completed and how this differs by whether respondents took the ascending or descending path. The number of completed rounds is significantly

[6]See, for example Whittington *et al.* (1990); Carson & Groves (2007) for a discussion of biases involved in CV studies.

[7]The use of the different starting values allows us to account for starting point bias, also known as the anchoring effect. See, for example Herriges & Shogren (1996a); Sievert & Steinbuks (2020).

larger for respondents on the descending path.[8]

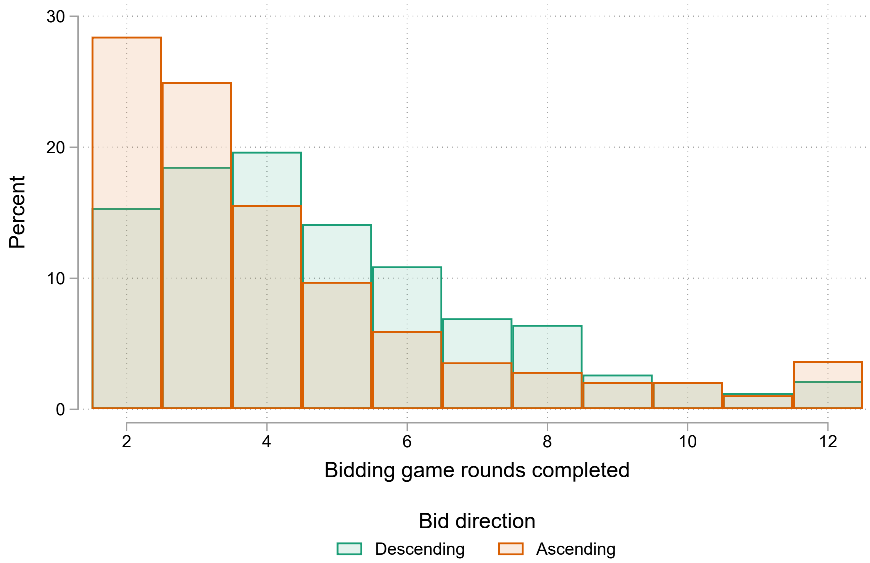


Figure 2: Number of rounds answered by household respondents

After responding to the primary WTP scenario, for high-quality service, households and firms were asked about two additional scenarios: half as many power cuts as currently experienced, and half as many voltage drops as currently experienced.[9] A random percentage f was drawn from [40%,55%,70%,85%,100%] and respondents were asked if they would be willing to pay $f * wtp$ where WTP is the last price they accept in the primary WTP elicitation. After the initial random draw, future price increased (decreased) by 115% (85%) as above. Up to five total rounds were asked for each scenario.

3 Methods

3.1 Cross-sectional WTP by households and firms

The WTP elicitation method in the survey follows a multiple-bound dichotomous choice design (DCm). The data generating process resembles an ordered probit model in which the

[8]A common concern in CV studies is the presence of *protest bidding*, a situation in which some respondents are unwilling to pay any extra cost for improved services or feel that it is not their responsibility to do so. In our study, we find no evidence of protest bidding. Of the 40% of respondents who answer "no" to the initial random price offer, only 2.7% respond "no" to all twelve price offers, and only one respondent answer 0 to the open-ended follow-up question. Moreover, our results are robust to excluding respondents who answer "no" to all twelve offers.

[9]Note: due to a survey programming error, for firms we only have results about power cuts.

thresholds are known. Therefore, we modify the likelihood function of the ordered probit model to account for the fact that the threshold values are known and employ maximum likelihood estimation.[10] This approach extends the double bounded (or interval) model formalized by Lopez-Feldman (2012) and applied in Oseni (2017) to estimate the WTP for reliable electricity in Nigeria.

More specifically, let $t_i = t_i^1, \ldots, t_i^J$ denote the predetermined randomized values that differ across individuals, i, and $y_i = y_i^1, \ldots, y_i^J$ denote the dichotomous answer regarding the willingness to pay for that specified amount. Then $y_i^j = 1$ if individual i is willing to pay amount y_i^j and 0 otherwise. Furthermore, let z_i denote the vector of explanatory variables and β a corresponding vector of coefficients. Define an individual's unique willingness to pay (WTP) as:

$$WTP_i = \mathbf{z_i}'\beta + u_i \tag{1}$$

where u_i denotes the error term.

A respondent will answer yes ($y_i^j = 1$) when his/her WTP exceeds the suggested amount t_i^j, such that $WTP_i > t_i^j$ and no otherwise. The first answer determines whether the bids are ascending (if $y_i^1 = 1$) or descending (if $y_i^1 = 0$). Given that each respondent can be presented with $j = 1, \ldots, J$ suggested amounts, the likelihood function comprises $2 * J$ terms. In case of ascending bids, the potential responses are as follows: $\{yes, no\}$, $\{yes, yes, no\}$, $\{yes, yes, yes, no\}$,..., $\{yes, yes, yes, \ldots, yes\}$. In the case of descending bids, the answers take the following reverse pattern: $\{no, yes\}$, $\{no, no, yes\}$, $\{no, no, no, yes\}$,..., $\{no, no, no, \ldots, no\}$. Therefore, assuming that the error term is normally distributed, $u_i \sim N(0, \sigma^2)$, the probability that the individual's WTP will fall between two subsequent values t^{j-1} and t^j for $j = \{2, \ldots, J\}$ when the respondent is on the ascending path (i.e. $y_i^1 = 1$)

[10] This is equivalent to interval regression.

can be expressed as:

$$\begin{aligned}
\Pr(y_i^{j-1}=1, y_i^j=0|\mathbf{z_i}) &= \Pr(t_i^{j-1} \leq WTP < t_i^j|\mathbf{z_i}) \\
&= \Pr(t_i^{j-1} \leq \mathbf{z_i}'\beta + u_i < t_i^j|\mathbf{z_i}) \\
&= \Pr\left(\frac{t_i^{j-1} - \mathbf{z_i}'\beta}{\sigma} \leq \frac{v_i}{\sigma} < \frac{t_i^j - \mathbf{z_i}'\beta}{\sigma}\right) \\
&= \Phi\left(\frac{t_i^j - \mathbf{z_i}'\beta}{\sigma}\right) - \Phi\left(\frac{t_i^{j-1} - \mathbf{z_i}'\beta}{\sigma}\right)
\end{aligned} \tag{2}$$

where $v_i \sim N(0,1)$ and Φ denotes the cdf of the standard normal distribution. When the respondent is instead on the descending path (i.e. $y_i^1 = 0$) the probability that his/her WTP falls between two subsequent values t^j and t^{j-1} for $j = \{2, \ldots, J\}$ can be expressed as:

$$\begin{aligned}
\Pr(y_i^{j-1}=0, y_i^j=1|\mathbf{z_i}) &= \Pr(t_i^j \leq WTP < t_i^{j-1}|\mathbf{z_i}) \\
&= \Pr(t_i^j \leq \mathbf{z_i}'\beta + u_i < t_i^{j-1}|\mathbf{z_i}) \\
&= \Pr\left(\frac{t_i^j - \mathbf{z_i}'\beta}{\sigma} \leq \frac{v_i}{\sigma} < \frac{t_i^{j-1} - \mathbf{z_i}'\beta}{\sigma}\right) \\
&= \Phi\left(\frac{t_i^{j-1} - \mathbf{z_i}'\beta}{\sigma}\right) - \Phi\left(\frac{t_i^j - \mathbf{z_i}'\beta}{\sigma}\right)
\end{aligned} \tag{3}$$

The probability that the respondent's WTP exceeds all suggested bids (i.e. respondent i answered "yes" to all suggested values) is equal to:

$$\begin{aligned}
\Pr(y_i^1 = 1, \ldots, y_i^J = 1|\mathbf{z_i}) &= \Pr(WTP > t_i^J|\mathbf{z_i}) \\
&= \Pr(\mathbf{z_i}'\beta + u_i > t_i^J|\mathbf{z_i}) \\
&= \Pr\left(\frac{v_i}{\sigma} > \frac{t_i^J - \mathbf{z_i}'\beta}{\sigma}\right) \\
&= 1 - \Phi\left(\frac{t_i^J - \mathbf{z_i}'\beta}{\sigma}\right)
\end{aligned} \tag{4}$$

And similarly, the probability that the respondent's WTP is lower than the lowest value of the suggested bids (i.e. respondent i answered "no" to all suggested values) is equal to:

$$\begin{aligned}
\Pr(y_i^1 = 0, \ldots, y_i^J = 0|\mathbf{z_i}) &= \Pr(WTP < t_i^J|\mathbf{z_i}) \\
&= \Pr(\mathbf{z_i}'\beta + u_i < t_i^J|\mathbf{z_i}) \\
&= \Pr\left(\frac{v_i}{\sigma} < \frac{t_i^J - \mathbf{z_i}'\beta}{\sigma}\right) \\
&= \Phi\left(\frac{t_i^J - \mathbf{z_i}'\beta}{\sigma}\right)
\end{aligned} \tag{5}$$

Note that, while in general with an ordered probit model, one would need to assume that $\sigma^2 = 1$, we do not need to make that normalization when the cut-off points are known. As in case of an ordered probit, we estimate the parameter vector of interest, β, using maximum likelihood. Given the above equations for possible probabilities, the likelihood function becomes:

$$\begin{aligned}
\mathcal{L} = & \sum_{i=1}^{N} \{d_i^{y^{j-1}=1,y^j=0} ln(\Phi(\frac{t_i^j - \mathbf{z_i}'\beta}{\sigma}) - \Phi(\frac{t_i^{j-1} - \mathbf{z_i}'\beta}{\sigma})) \\
+ & \; d_i^{y^1=1,\ldots,y^J=1} ln(1 - \Phi(\frac{t_i^J - \mathbf{z_i}'\beta}{\sigma})) \\
+ & \; d_i^{y^{j-1}=0,y^j=1} ln(\Phi(\frac{t_i^{j-1} - \mathbf{z_i}'\beta}{\sigma}) - \Phi(\frac{t_i^j - \mathbf{z_i}'\beta}{\sigma})) \\
+ & \; d_i^{y^1=0,\ldots,y^J=0} ln(\Phi(\frac{t_i^J - \mathbf{z_i}'\beta}{\sigma}))\}
\end{aligned} \tag{6}$$

where $d_i^{y^{j-1}=1,y^j=0}$, $d_i^{y^1=1,\ldots,y^J=1}$,$d_i^{y^{j-1}=0,y^j=1}$,$d_i^{y^1=0,\ldots,y^J=0}$ are indicator variables denoting which case an individual falls into.

In the results presented below, we take the logarithm of the interval boundaries t_i^j. For the covariate matrix $\mathbf{z_i}$, we follow previous empirical work and include several individual and household characteristics. Specifically, we include respondent age, gender, formal education dummy, literacy (in French and local languages), employment status, and household head status. At a household level, we control for the household's main source of income (agriculture, services, commerce or other), expenditure level (Q1-Q5 measured as dummy variables indicating whether the household's expenditures falls in given quintile of the distribution of expenditures), and the size of the household (measured by the number of residents). We also control for whether a household has savings in the form of a bank account, the ownership status of the dwelling, and whether electricity was mainly used for economic, domestic or leisure purposes We also include region and interviewer fixed effects to account for his/her idiosyncratic ability and behavior. Finally, we control for the initial bid level as previous work suggests it can be a source of bias (Boyle *et al.*, 1997).

One potential source of heterogeneity of particular interest is whether the WTP for high-quality service is related to current service quality. Households experiencing frequent or lengthy power interruptions may have a higher WTP than households already receiving relatively high-quality service. To test for this heterogeneity, we include a dummy for households who report experiencing power outages.

A primary critique of this type of WTP model is that it relies on the assumption that there is a single underlying latent WTP process. Several studies have raised concerns that dichotomous-choice designs can lead to answers that are internally inconsistent. The starting point may be a source of bias (Herriges & Shogren, 1996b; Boyle *et al.*, 1997). Bateman *et al.* (2001) extend this result to double- and triple-bounded designs, identifying both starting-point and path effects. In our results below, we extend these results by testing for the presence of starting-point and path effects.[11]

3.2 Panel-like structure for a subset of households

For a subset of our sample (863 households), the dataset contains responses from two household members. In this case, for each household h, we observe the WTP for a male and a female respondents. This gives us a unique opportunity to exploit the "panel-like" structure of the data and account for unobserved household level characteristics.[12] We can decompose the error term in the WTP equations for male (m) and female (f) members of households to a household specific component, ν_h, and the idiosyncratic part, ε_m and ε_f, respectively. Then assuming that $\nu_h \sim N(0, \sigma_\nu^2)$ and the household specific effects are not correlated with the other regressors in the willingness to pay equation (i.e., we assume a random effects structure), we can construct a likelihood function. However, given that the household specific effects are likely to be correlated with other regressors in the model, we apply the Mundlak (1978) correction and model the household level individual effects as a function of household level averages of some of the regressors, i.e. we include averages of

[11] One avenue for further investigating this approach might be to adapt the methods in Cameron & Quiggin (1994).

[12] This is also useful in light of the results in Prabhu (2010) which reject a model of common household preferences.

those regressors at a household level as additional variables. This approach is particularly attractive for assessing the differences between genders in terms of WTP. Assuming a normal distribution, $N \sim (0, \sigma^2_{v_h})$ for the random effects v_h each individual contribution to the likelihood function is:

$$l_h = \int_{-\infty}^{\infty} \frac{e^{-v_h^2/2\sigma_v^2}}{\sqrt{2\pi\sigma_v^2}} \{\Pi_{t=1}^{2} F(t_{1ht}, t_{2ht}, \mathbf{z}_{ht}\beta + v_h)\} dv_h$$

where $F(\cdot)$ is defined analogous to the probabilities above and the log likelihood $\mathcal{L}$ is the sum of the logs of the individual level likelihoods l_h.

4 Results: WTP for improved electricity

4.1 Cross-sectional analysis (households)

In this section, we present results from the cross-sectional analysis of individual WTP for improved electricity services among already-connected households. We first test and reject the assumption of a single underlying latent WTP process. We then present results from single-bound, double-bound, and multiple-bound models. Finally, we discuss the interpretation of the results and potential policy implications.

A fundamental underlying assumption of WTP estimation using a multiple-bound DCm design is that the latent distribution of resource values is consistent across rounds. If the underlying WTP distribution is significantly different in follow-up rounds relative to the distribution implied by the first-round responses, this could suggest that the results using follow-up bids are biased. To test this assumption in our data, we estimate a model including interaction terms between all regressors and dummy variables indicating the number of completed rounds in the bidding game. If the coefficients on the interaction terms are jointly not statistically different from zero, we can conclude that this assumption holds. If, however, we find that the coefficients are jointly different from zero, then we should interpret with caution results from models incorporating multiple rounds of responses. For 2, 3, and 6 rounds, we reject the hypothesis that the β coefficients do not differ between the rounds. Therefore,[13] we conclude that the main underlying assumption in the above-mentioned

[13] Since this substantially increases the number of coefficients to be estimated and since in Table B.7 it appears that the coefficients are very similar between 6 and 12 rounds, we perform this exercise for up to 6 rounds the bidding game. Detailed results can be obtained from the authors on demand. All p-values were 0.000.

likelihood estimation does not hold in the data.[14]

Although we are unable to support the assumption of consistent underlying value distribution, in practice, the bias may be small. If the resulting distributions are not very different, we could conclude that it has a limited effect on the primary estimate of interest, i.e., the WTP for reliable electricity. Thus, we proceed with estimating the WTP using different models given different assumptions about the number of rounds in the game. We first estimate the implied WTP resulting from a single-bound model (Bishop & Heberlein, 1979), in which we consider only the initial bid. Coefficients in the latent WTP equation (β) are obtained via a transformation proposed by Cameron & James (1987): $\beta = \gamma_1/\gamma_0$ where γ_1 denotes the probit estimates and γ_0 the estimate on the initial bid. Then, we estimate a double-bound model where we consider the initial bid and a single follow-up (Hanemann *et al.*, 1991). Next, we estimate multiple-bound models using 3, 5, and all 11 follow-up bids. Lastly, we compare the results of this probit estimation to results obtained by assigning individuals to the midpoint of the appropriate valuation interval[15] and estimating the parameters using OLS.

The results of this exercise are summarized in Figure 3 (see Appendix B for a full corresponding table of coefficients, noting that the coefficient from the binary model cannot be directly compared to coefficients from the models with multiple follow-up rounds). We find that the distributions are visibly similar for all models except for the scenarios where only the first round of the bidding game is considered. Figure 4 compares the estimated WTP at three points of the distributions: 25^{th}, 50^{th} and 75^{th} percentile and further confirms the significant differences between the estimated WTP when only the initial bid is considered and when follow up questions are included in the estimation. The estimates of the probit model rarely coincide with the confidence intervals of the estimates from the other models, suggesting statistically significant differences in the estimates. One of the reasons we observe the above patterns is that some respondents might not fully understand the question initially.

[14]The validity of this test relies on the assumption that the number of rounds is exogenous. This might not be the case even in the situation where bids are either increasing or decreasing. Therefore, we perform two additional checks. First, we conduct a test of equality of coefficients between the specifications, assuming a different number of rounds in the bidding game. Second, since all respondents participated in at least two rounds, we limit the sample to respondents who finished after the first follow-up question and perform a test for equality of the coefficients between a binary model (using only the first round) and an interval regression (using both rounds). Both checks lead to the rejection of the null hypothesis suggesting that coefficients differ between the specifications and violation of the unique valuation assumption.

[15]These midpoints are assigned using the ultimate and penultimate values offered in the CV exercise, or the open-ended response and the final value if the respondents responded 'yes' or 'no' to all twelve rounds.

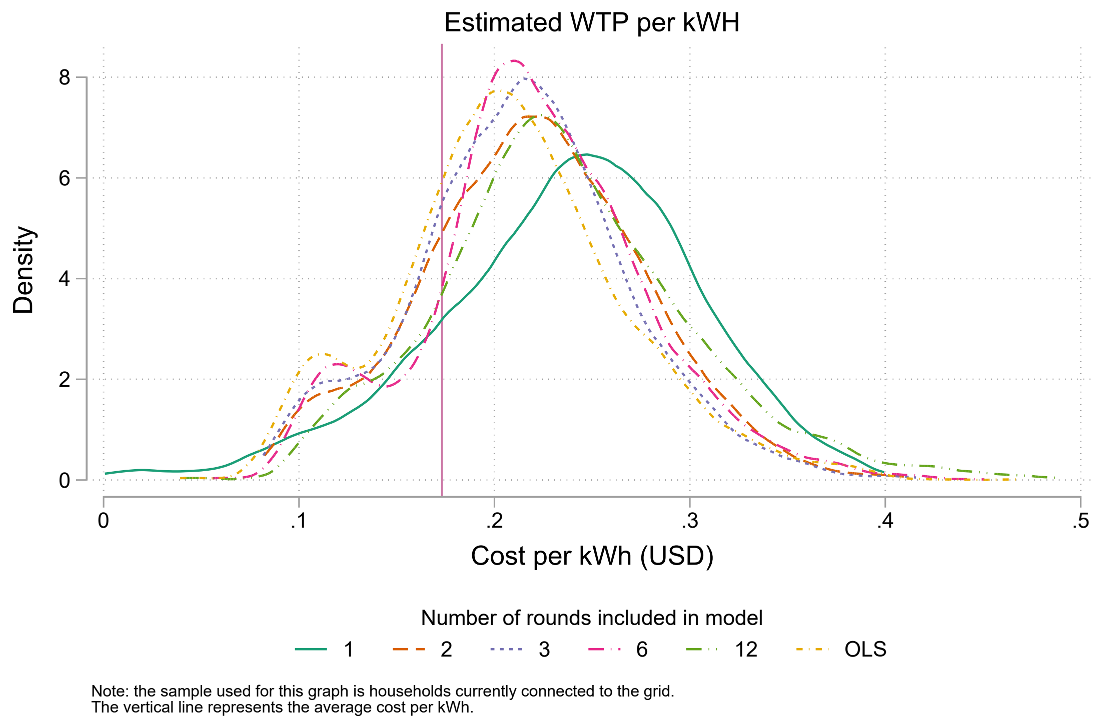
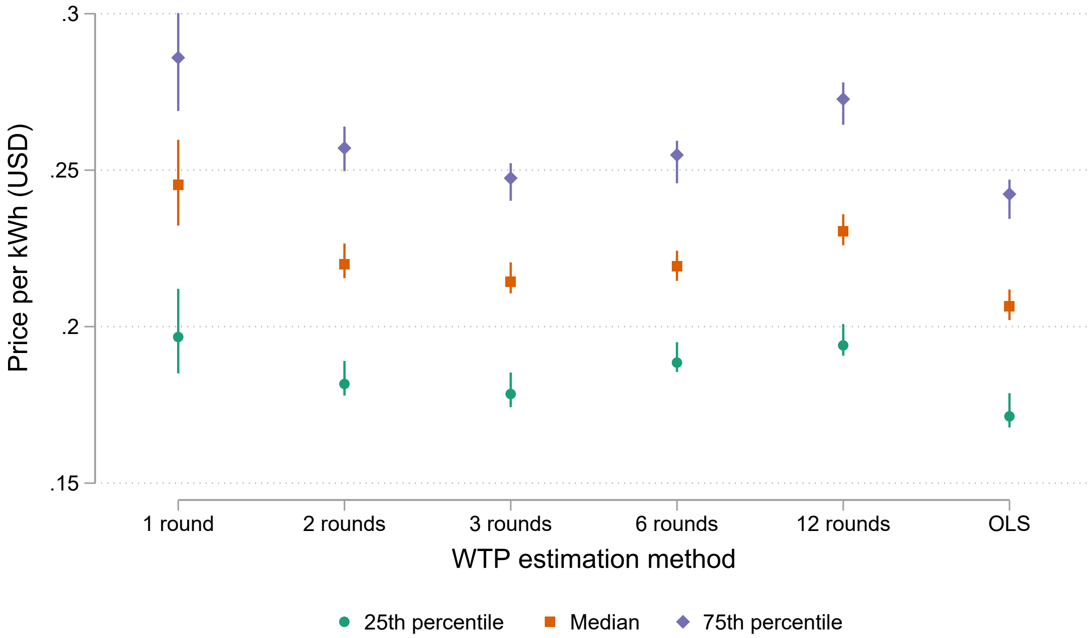


Figure 3: WTP per kWh, households (cross-sectional)

It could also be the case that enumerators become better at administering the question over time. To shed light on the latter issue, we estimate the model excluding the first 10, 25, and 50 percent of the respondents, respectively. Figures B.11 and B.12 present results of the WTP estimation and bootstrapped percentile comparison when we restrict to the latter half of surveys completed. These results are less precise, due to the decreased sample size, but they demonstrate similar patterns to those shown in the full sample, noting that the distributions appear more alike. This is suggestive that the enumerators indeed excel in administering the questions over time.

Looking at the predictors of WTP, we consistently find that younger respondents with savings in a form of a bank account report statistically significant higher WTP for the improved service. We also find that gender yields an inconsistent result across models. In most models, we find that women are willing to pay significantly less than men for reliable electricity. However, the full 12-round model finds the opposite result, that females are willing to pay significantly more than males. It could be that women are more prone to the *yea-saying* bias but further work is needed to better understand the gender heterogeneity in WTP, and whether these differences are meaningful for policy.

Figure 4: Percentile comparisons of WTP estimates by method



Note: Percentiles bootstrapped using 2000 replications. 1 round results come from a probit using only the initial response to a randomly drawn value. 2, 3, 6, and 12 rounds use additional rounds of the bidding game to estimate WTP using interval regressions. OLS uses the midpoint between the ultimate and penultimate responses for each respondent. All plots show 95% confidence intervals.

Importantly, results from all models suggest that a vast majority of households are willing to pay a price per kWh which is meaningfully higher than the average estimated rate households are currently paying in the data ($0.17 per kWh). Table 1 shows that across the models, we find a similar result that households are willing to pay 24-35 percent more than the current average price per kWh for reliable electricity. As in Bateman *et al.* (2001), we do find that initially increasing the number of follow-up questions results in lower average WTP among households. However, moving beyond two follow up rounds shows an increase in estimated WTP at all three points of the distribution, suggesting that some *yea-saying* effect might be present with more rounds. The difference is of economic importance, since as Figure 3 shows, the single-bound model shows a flatter distribution but one centered at a higher average WTP. Therefore, any policy recommendation based on DCm designs under the assumption of a unique latent valuation process should first check that assumption and consider the implications of its violation.

Table 1: Household WTP compared to mean reported price per kWh

	1	2	3	6	12	OLS
Percentage with WTP > mean price	0.84	0.80	0.79	0.83	0.85	0.74
Mean difference (WTP - mean price)	0.06	0.05	0.04	0.05	0.06	0.03
Median difference (WTP - mean price)	0.07	0.05	0.04	0.05	0.06	0.03

4.2 Panel-like analysis (households)

We next present the results of the random effects model for the households for which two respondents, male and female, answered the questionnaire. By doing so, we can improve the efficiency of the estimates by comparing individuals within a household and thus assume away the confounding effect of unobserved household level characteristics.[16] As above, given the concerns about bias in the multiple-bound models, we estimate several models with different restrictions on the number of rounds considered.

Figure 5 (analogous to Figure 3 above) shows the overall distribution of willingness to pay by respondents. The figure suggests that, in general, the distributions of WTP are quite similar to the distributions obtained in the cross-sectional analysis. Moreover, we again find willingness to pay that is substantially higher than the mean price currently paid by households (see Appendix B for a full corresponding table of coefficients).

As in case of cross-sectional analysis, the models do not give consistent results about relative WTP by males and females. While certain individual characteristics appear significant in some models, no predictor is consistently significant in all models, further stressing the importance of modeling choices for drawing conclusions and informing policy makers.

4.3 Cross-sectional analysis (formal and informal firms)

We next turn to the estimation of the WTP among enterprises. As with the household sample, we report results from a number of models, and compare with results from OLS with the interval midpoint as the outcome. More precisely, we estimate a single-bound probit model, interval regressions with results from 2, 3, 6, and all 12 rounds of the elicitation bidding game, and compare with results estimated via OLS on the midpoint of the intervals.

Similarly to the household sample, we find that younger entrepreneurs express higher WTP than their older counterparts. All other predictors are insignificant across all models,

[16] Results show that indeed panel level effects are present (LR test, p-value=0.000).

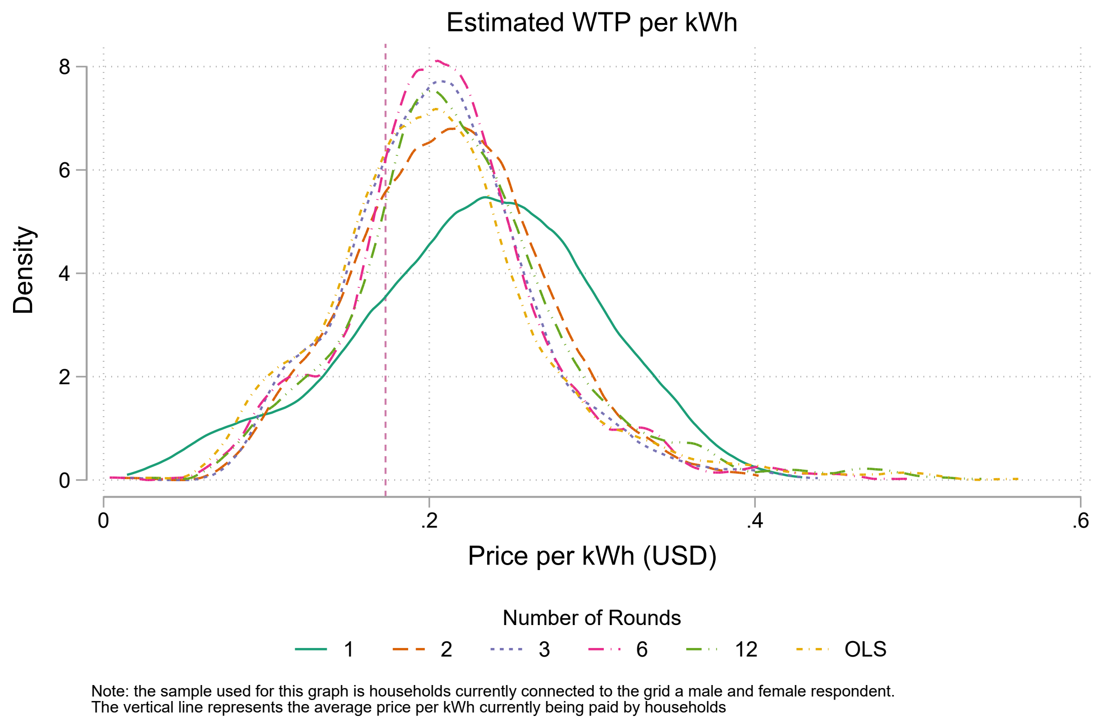


Figure 5: WTP per kWh, households (panel-like)

noting that the sample size is much smaller than in the case of households, which could explain the drop in precision.

Importantly, as with households, we find that firms report positive and economically significant WTP for improved electricity services. Figure 6 shows the distribution of the WTP estimated from different models. Unlike the household sample, we find substantial deviation between models. Interestingly, the results which incorporate more rounds of bidding approach the single-bound results more closely. This may be an avenue for future research.

When considering the policy implications of these WTP estimates, we first note that firms in the sample report paying almost 50% more per kWh than households. The median formal firm reports paying \$0.28/kWh, whereas the median informal firm reports paying \$0.23/kWh. We do find that a meaningful proportion of firms are willing to pay more than the current average price, but the proportion varies widely across models and firm status (formal/informal). Table 2 summarizes these results for both formal and informal firms, noting that a significantly higher share of formal firms WTP exceeds the current prices. Seventy-two to eighty-eight percent of formal firms and fourty-eight to seventy-six percent of

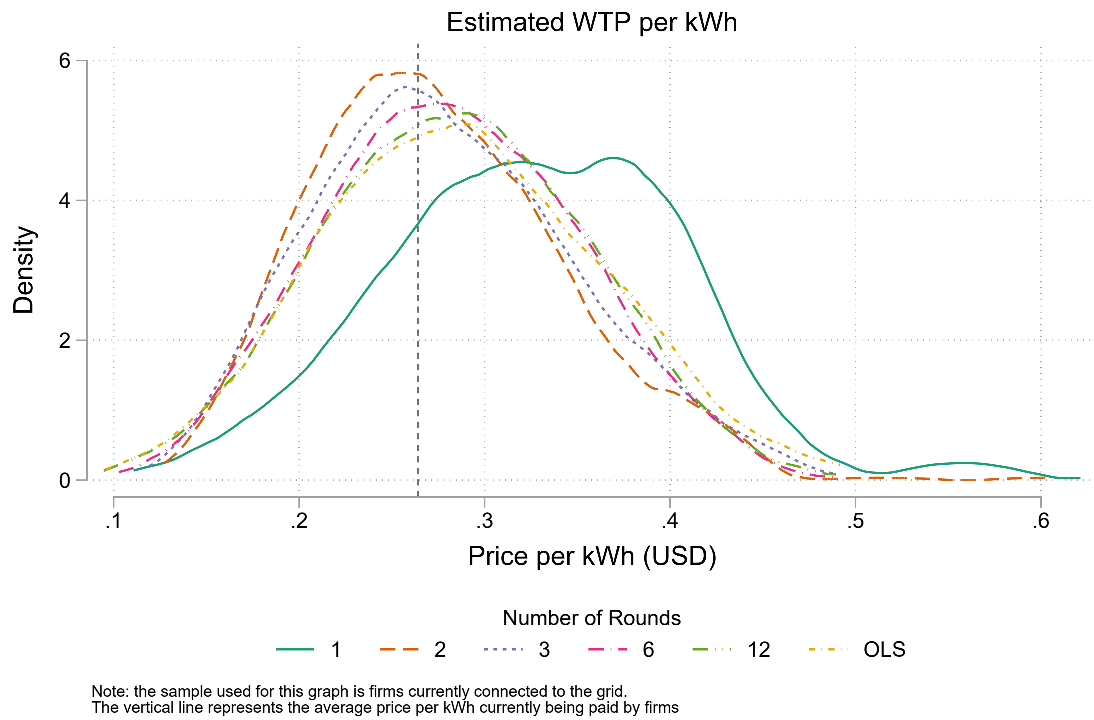


Figure 6: WTP per kWh, firms

informal firms express WTP above the current price. This large discrepancy between formal and informal firms is not surprising, given that formal firms in our sample are more likely to report income losses from power cuts (see Table A.6). By contrast, the current average price that the informal firms face is close to average household WTP for improved service. Given that many informal firms are closely linked with households, this could explain why a lower share of informal firms are willing to pay more than the current average price. Moreover, this evidence is suggestive that households can benefit economically from access to high-quality electricity through economic opportunities that such access provides. Nevertheless, the large discrepancy of our estimates suggests caution for policymakers in deciding how to set tariffs for improved service for firms.

4.4 WTP for marginal service improvements

Until now, we have focused on the WTP for high-quality electricity service without outages. Next, we turn to the estimation of the WTP for marginal service improvements–a 50% reduction in power outages and voltage drops. This comparison is important to policy

Table 2: Firm WTP compared to mean reported price per kWh

	1	2	3	6	12	OLS
Formal						
Percentage with WTP > mean price	0.87	0.74	0.76	0.74	0.73	0.72
Mean difference (WTP - mean price)	0.11	0.05	0.07	0.05	0.05	0.05
Median difference (WTP - mean price)	0.11	0.05	0.06	0.07	0.06	0.06
Informal						
Percentage with WTP > mean price	0.75	0.46	0.49	0.54	0.57	0.57
Mean difference (WTP - mean price)	0.05	−0.00	0.00	0.01	0.01	0.01
Median difference (WTP - mean price)	0.05	−0.01	−0.00	0.01	0.01	0.01

makers as incremental improvements in service quality might not result in the same WTP as significant and salient improvements. We report results comparing the WTP using all rounds of data, so 12 rounds from the primary elicitation and 5 rounds from both additional scenarios. Figures 7 and 8 present the results of these exercises for households and firms, respectively. Both figures demonstrate important gaps between the WTP for ideal service and the WTP for marginal improvements. These results confirm that the type of improvement in quality matters for policy: electricity providers may find it more difficult to raise tariffs if service improvements are perceived as marginal. These results could also explain why protests erupted in Senegal in 2019 after an increase in tariffs despite improvements in the quality of service. Given that prices in Senegal are already high relative to neighboring countries (Huenteler *et al.*, 2020), further price increases may require large, salient improvements in quality. In general, our results suggest households may perceive incremental improvements differently than a fully-optimized service.

Moreover, we can use the comparison between WTP for different levels of improvements to validate the respondents' responses. We find that the vast majority of responses are internally consistent, i.e., the WTP estimated for marginal service improvements is lower than the WTP estimated for ideal service (i.e., 24/7 availability). Results presented here and above are robust to excluding households and firms for whom the responses are not internally consistent.[17]

[17] These results also highlight that comparisons between different studies need to account for the type of improvements offered to respondents in the WTP elicitation process. See B.10 in the Appendix for a brief summary of a few studies.

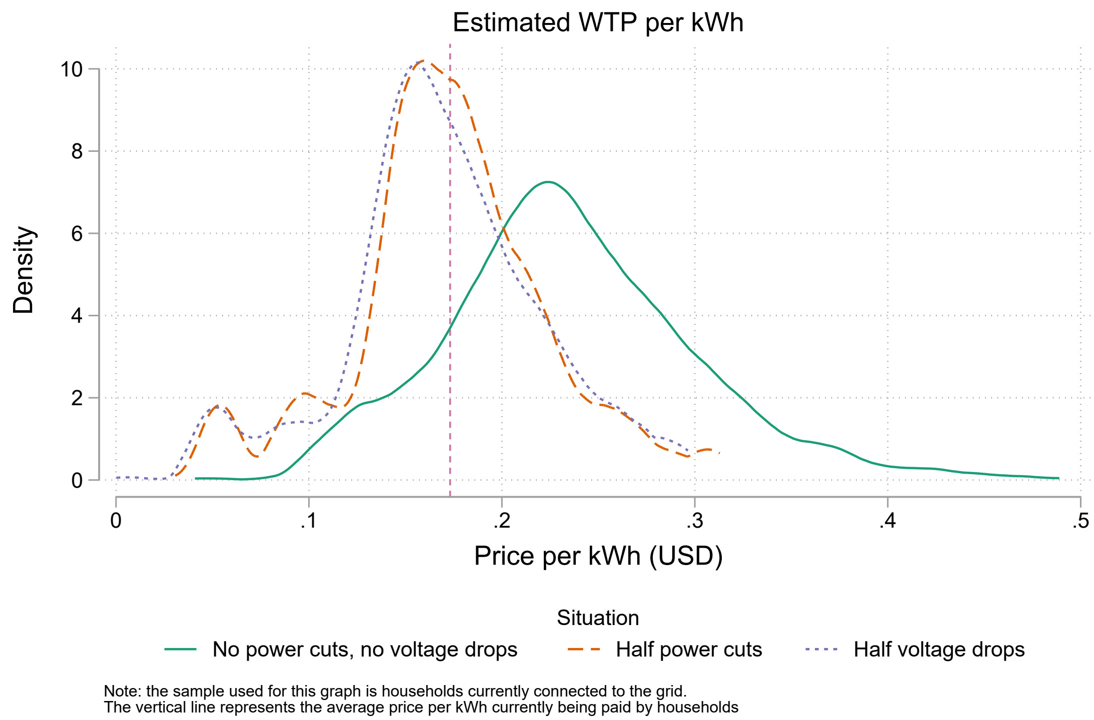


Figure 7: WTP by scenario (households)

5 Conclusions

Using new data and a variety of modeling approaches, we estimate the willingness to pay for improved electricity services among households and enterprises in Senegal. Our results are important for at least three reasons.

First, we find that households and firms are willing to pay a statistically and economically significant premium over current tariffs for high-quality electricity service without outages. Household are willing to pay 24-35% more than the current average price ($0.17 per kWh). Among firms, even though the price they report is almost 50% more per kWh than households, about 80% of formal firms and 50% of informal firms are willing to pay a higher price than what they already pay. This result is of fundamental importance for policymakers in Senegal (and very likely in other low-income countries) who face a significant challenge to fully recover the cost of producing and distributing electricity to households and firms. It is estimated that the national utility company (SENELEC), which supplies most of the electricity in Senegal, can only recover about 70 percent of its total costs (Huenteler *et al.*, 2020). To remain viable, SENELEC relies on government fiscal transfers to compensate for the shortfall

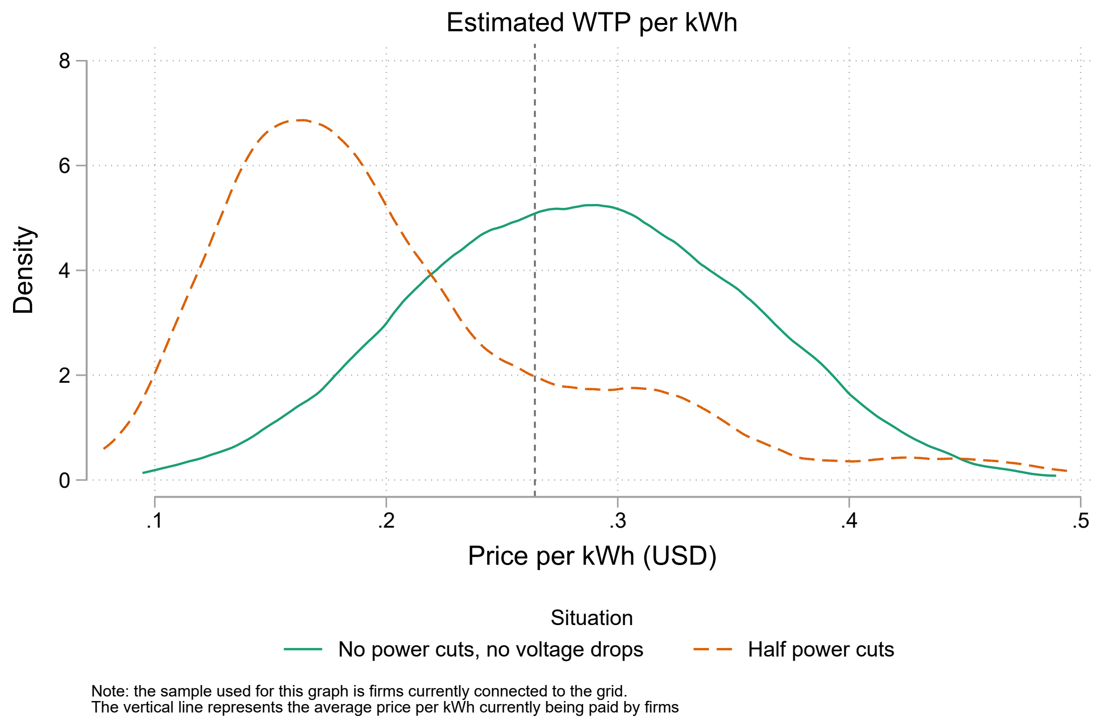


Figure 8: WTP by scenario (firms)

in tariff revenues, which is exacerbated by the fact that many public institutions often do not pay their electricity bills (Foster & Rana, 2019). One way to improve the viability of SENELEC is to increase tariffs paid by households and firms. Our results show that this indeed might be a way forward for policymakers to raise the needed revenue to ensure the power sector sustainability.

Second, our results show that for the households and firms to be willing to pay higher tariffs, the quality of the service needs to improve substantially. We find that WTP for marginal service improvements is significantly lower than WTP for uninterrupted service. Therefore, policymakers would be hard-pressed to raise the electricity tariffs if they are not accompanied by a substantial improvement in the quality of service offered as any service improvement perceived by households and firms as marginal with respect to the tariff increase may meet resistance or opposition. This is especially true in Senegal whose competitiveness in the West African region is severely hampered by the high cost of electricity relative to its neighboring countries. In sum, when contemplating tariff increase, policymakers may need to be cautious not to increase tariffs above the estimated WTP for households and firms and strive to first ameliorate the quality of electricity service in the country. Doing so has the potential to generate positive externalities for other sectors of the economy and boost overall economic growth. Future work could extend this to conduct a more thorough cost-benefit analysis.

Third, we also discuss the importance of the design choices in applying CV methods to estimate willingness to pay. We illustrate that in any DCm design, it is crucial to check the data against the single valuation assumption. Failure to do so may result in a significant downward bias of the WTP estimates. Given that studies aiming at estimating WTP often take this assumption for granted, our results should serve as a cautionary tale for future practitioners.

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Appendix

A Additional Summary Statistics

Table A.3: Respondent characteristics

	Male	Female
Respondent age	47.31	41.48
	(14.81)	(13.18)
Any education	0.530	0.383
	(0.499)	(0.486)
Household head	0.773	0.342
	(0.419)	(0.474)
Married	0.859	0.797
	(0.348)	(0.402)
Employed	0.758	0.554
	(0.429)	(0.497)
Literate (French)	0.483	0.312
	(0.500)	(0.463)
Literate (local lang)	0.388	0.344
	(0.487)	(0.475)

mean coefficients; sd in parentheses

Table A.4: Characteristics of urban and rural households

	(1) Urban		(2) Rural		T-test Difference
Variable	N	Mean/SE	N	Mean/SE	(1)-(2)
Bank account	1485	0.190	1290	0.104	0.086***
		(0.010)		(0.008)	
Household size	1485	8.627	1290	11.369	-2.742***
		(0.161)		(0.252)	
Owns home	1485	0.556	1290	0.854	-0.298***
		(0.013)		(0.010)	
Connected to grid	1485	0.876	1290	0.775	0.101***
		(0.009)		(0.012)	
Non electricity energy expenses per month (USD)	1485	13.855	1290	9.944	3.910***
		(0.420)		(0.342)	
Estimated cost per kWh (USD) [connected only]	1299	0.173	1000	0.173	0.000**
		(0.000)		(0.000)	

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table A.5: Characteristics of connected and unconnected households

	(1) Not connected		(2) Connected to grid		T-test Difference
Variable	N	Mean/SE	N	Mean/SE	(1)-(2)
Bank account	474	0.021	2299	0.177	-0.156***
		(0.007)		(0.008)	
Household size	474	8.219	2299	10.252	-2.033***
		(0.281)		(0.167)	
Owns home	474	0.679	2299	0.699	-0.019
		(0.021)		(0.010)	
Non electricity energy exp per month (USD)	474	10.192	2299	12.414	-2.223***
		(0.567)		(0.314)	

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table A.6: Characteristics of formal and informal firms

	(1) Informal		(2) Formal		T-test Difference
Variable	N	Mean/SE	N	Mean/SE	(1)-(2)
Firm age	866	11.855	206	14.951	-3.097***
		(0.371)		(0.944)	
Rural	866	0.370	206	0.063	0.306***
		(0.016)		(0.017)	
Number of employees	814	3.262	194	13.052	-9.790***
		(0.313)		(2.148)	
Home business	814	0.168	194	0.067	0.101***
		(0.013)		(0.018)	
Experiences power cuts	538	0.771	188	0.777	-0.005
		(0.018)		(0.030)	
Reports income loss from power cuts	538	0.680	188	0.766	-0.086**
		(0.020)		(0.031)	
Firm head age	866	44.024	206	49.136	-5.112***
		(0.482)		(0.941)	
Firm head female	866	0.197	206	0.126	0.071**
		(0.014)		(0.023)	
Firm head attended at most primary school	866	0.211	206	0.063	0.148***
		(0.014)		(0.017)	
Firm head attended at most high school	866	0.065	206	0.131	-0.066***
		(0.008)		(0.024)	
Firm head attended at least college	866	0.169	206	0.680	-0.511***
		(0.013)		(0.033)	
Estimated cost per kWh (USD)	496	0.263	179	0.289	-0.025**
		(0.006)		(0.009)	
Firm head is owner	866	0.881	206	0.646	0.235***
		(0.011)		(0.033)	
Connected to grid	814	0.661	194	0.969	-0.308***
		(0.017)		(0.012)	

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

B More on WTP estimates

Table B.7: Household WTP for improved electricity service

	(1)	(2)	(3)	(4)	(5)	(6)
	1	2	3	6	12	OLS
Starting value	-11.00***	0.71***	1.17***	1.59***	2.11***	0.95***
	(0.60)	(0.23)	(0.18)	(0.18)	(0.19)	(0.19)
Female	-0.17***	-0.04*	-0.01	0.07***	0.18***	-0.08***
	(0.06)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Experiences power	-0.05	-0.03	-0.01	-0.01	-0.04	-0.01
cuts	(0.08)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
Age	-0.00**	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Formal ed (0/1)	0.01	0.00	0.00	0.01	0.00	-0.01
	(0.09)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
HH head	0.00	0.04	0.04**	0.04**	0.07***	0.03
	(0.07)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Married	-0.06	-0.02	-0.03	-0.02	-0.01	-0.02
	(0.07)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
Employed	0.11*	0.02	0.02	0.02	0.01	0.03
	(0.06)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Literate (French)	0.08	0.02	0.02	-0.00	0.00	0.02
	(0.09)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Literate (local	0.15*	0.04	0.04	0.05**	0.04	0.04
lang)	(0.08)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
HH size	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Bank account	0.16*	0.05*	0.04	0.06**	0.06**	0.07***

	(0.08)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
Tot. exp. quintile 2	-0.11	-0.03	-0.03	-0.03	-0.01	-0.05
	(0.10)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Tot. exp. quintile 3	-0.13	-0.06**	-0.03	-0.04	-0.02	-0.05
	(0.10)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Tot. exp. quintile 4	-0.20**	-0.07**	-0.03	-0.03	-0.04	-0.05
	(0.10)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Tot. exp. quintile 5	-0.12	-0.03	-0.00	-0.01	-0.00	-0.01
	(0.11)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)
Rural	0.03	0.01	0.01	-0.01	-0.02	0.00
	(0.07)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Income source:	0.08	0.03	0.01	-0.01	-0.01	-0.02
agriculture	(0.10)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Income source:	-0.10	-0.03	-0.04	-0.04*	-0.04*	-0.06**
commerce	(0.07)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Income source:	-0.13*	-0.03	-0.03	-0.02	-0.03	-0.05*
services	(0.08)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
Owns home	-0.10	-0.05**	-0.04*	-0.04*	-0.03	-0.04
	(0.07)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Observations	2995	2995	2995	2995	2995	2995
R^2						0.282

All regressions include region and enumerator fixed effects.

Table B.8: Household panel-like WTP for improved electricity service

	(1)	(2)	(3)	(4)	(5)	(6)
	1	2	3	6	12	OLS
Starting value	-19.80***	1.03***	1.16***	1.42***	1.75***	0.96***
	(1.98)	(0.28)	(0.22)	(0.19)	(0.20)	(0.21)
Female	-0.43***	-0.09***	-0.06***	-0.01	0.05***	-0.08***
	(0.15)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Experiences power cuts	-0.16	-0.05	-0.03	-0.02	-0.07	-0.03
	(0.25)	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)
Age	0.00	0.00	0.00	-0.00	-0.00	-0.00
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Formal ed (0/1)	-0.34	-0.06	-0.06	-0.01	-0.03	-0.07*
	(0.26)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
HH head	-0.11	-0.01	0.01	0.04*	0.03	0.05**
	(0.17)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Married	0.51*	0.04	0.04	0.02	-0.00	0.03
	(0.26)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)
Employed	0.12	0.00	0.01	-0.01	0.00	0.01
	(0.18)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)
Literate (French)	0.32	0.07	0.08*	0.05	0.07**	0.10**
	(0.26)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
Literate (local lang)	-0.12	-0.02	-0.01	0.02	0.02	0.03
	(0.30)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)
Mean age	-0.01	-0.00	-0.00*	-0.00	-0.00**	-0.00
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Mean formal ed	0.63	0.11	0.14*	0.10	0.09	0.11
	(0.44)	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)

Mean HH head	-0.70	-0.03	-0.03	-0.01	0.02	-0.06
	(0.60)	(0.11)	(0.10)	(0.11)	(0.11)	(0.13)
Mean married	-0.89**	-0.12	-0.08	-0.01	0.06	0.00
	(0.42)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)
Mean employed	0.05	0.05	0.04	0.03	0.00	-0.01
	(0.32)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)
Mean literate French	-0.29	-0.09	-0.15*	-0.11	-0.15*	-0.14
	(0.46)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)
Mean literate local	0.24	0.09	0.10	0.07	0.06	0.04
	(0.46)	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)
HH size	-0.00	0.00	-0.00	-0.00	0.00	-0.00
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Bank account	0.27	0.07	0.07	0.08*	0.08	0.11*
	(0.26)	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)
Tot. exp. quintile 2	-0.02	-0.02	0.01	-0.02	-0.01	-0.05
	(0.32)	(0.06)	(0.05)	(0.06)	(0.06)	(0.07)
Tot. exp. quintile 3	-0.19	-0.10*	-0.06	-0.08	-0.07	-0.10
	(0.31)	(0.06)	(0.05)	(0.06)	(0.06)	(0.07)
Tot. exp. quintile 4	-0.32	-0.07	-0.02	-0.00	0.02	-0.01
	(0.32)	(0.06)	(0.05)	(0.06)	(0.06)	(0.07)
Tot. exp. quintile 5	-0.14	-0.06	0.01	-0.01	0.02	-0.01
	(0.34)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)
Rural	-0.09	-0.05	-0.04	-0.06	-0.08*	-0.08*
	(0.22)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
Income source:	0.25	0.09*	0.05	0.02	-0.01	-0.02
agriculture	(0.27)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
Income source:	-0.22	-0.05	-0.04	-0.07	-0.08*	-0.09*

commerce	(0.22)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
Income source:	-0.58**	-0.05	-0.05	-0.06	-0.07	-0.09*
services	(0.23)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)
Owns home	-0.12	-0.04	-0.04	-0.05	-0.05	-0.04
	(0.21)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
Observations	1390	1390	1390	1390	1390	1390
R^2						

All regressions include region and enumerator fixed effects

Table B.9: Firm WTP for improved electricity service

	(1) 1	(2) 2	(3) 3	(4) 6	(5) 12	(6) OLS
Starting value	-8.75***	2.07***	1.82***	1.63***	1.56***	1.51***
	(1.49)	(0.42)	(0.40)	(0.39)	(0.43)	(0.48)
Formal	0.41*	0.12**	0.15***	0.14**	0.12*	0.12*
	(0.22)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
Firm located in Dakar	0.09	0.02	0.03	0.03	0.04	0.03
	(0.19)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
Firm age	0.00	0.00	0.00	0.00	0.00	0.00
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Rural	0.10	0.02	-0.01	0.03	0.04	0.03
	(0.21)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)
Number of employees	0.01	0.00	0.01	0.00	0.00	0.00
	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Home business	0.06	-0.02	-0.02	-0.01	-0.04	-0.07
	(0.20)	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)
Log avg monthly revenue	-0.01	-0.00	-0.00	0.00	0.00	0.00
	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Turned a profit in 2017	0.05	0.04	0.05	0.04	0.06	0.07
	(0.19)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
Experiences power cuts	0.04	0.05	0.06	0.04	0.04	0.05
	(0.20)	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)
Reports income loss from power cuts	-0.09	0.00	0.00	0.01	0.01	-0.01
	(0.16)	(0.04)	(0.04)	(0.04)	(0.05)	(0.06)
Firm head female	0.02	-0.02	-0.06	-0.06	-0.04	-0.04
	(0.22)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
Firm head attended at most primary school	0.11	0.02	0.01	-0.00	-0.00	-0.01
	(0.21)	(0.05)	(0.06)	(0.06)	(0.06)	(0.07)
Firm head attended at most high school	0.13	0.12	0.05	0.03	0.03	0.01
	(0.28)	(0.07)	(0.07)	(0.07)	(0.08)	(0.09)
Firm head attended at least college	0.08	0.08	0.04	0.05	0.03	0.01
	(0.20)	(0.05)	(0.05)	(0.06)	(0.06)	(0.07)
Firm head age	-0.01	-0.00**	-0.01***	-0.01***	-0.01***	-0.01***
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Firm head is owner	0.19	0.11**	0.11**	0.13**	0.12**	0.12*
	(0.20)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
Observations	597	597	597	597	597	597
R^2						0.226

All regressions include region and enumerator fixed effects.

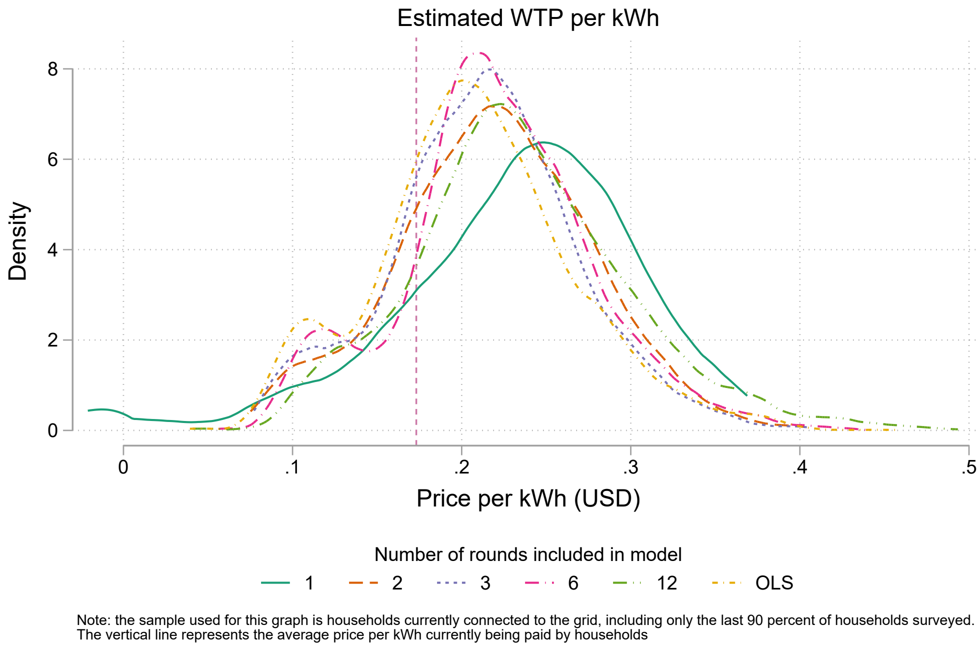

Figure B.9: WTP per kWh, households (cross-sectional), restricted to last 90% of surveys completed

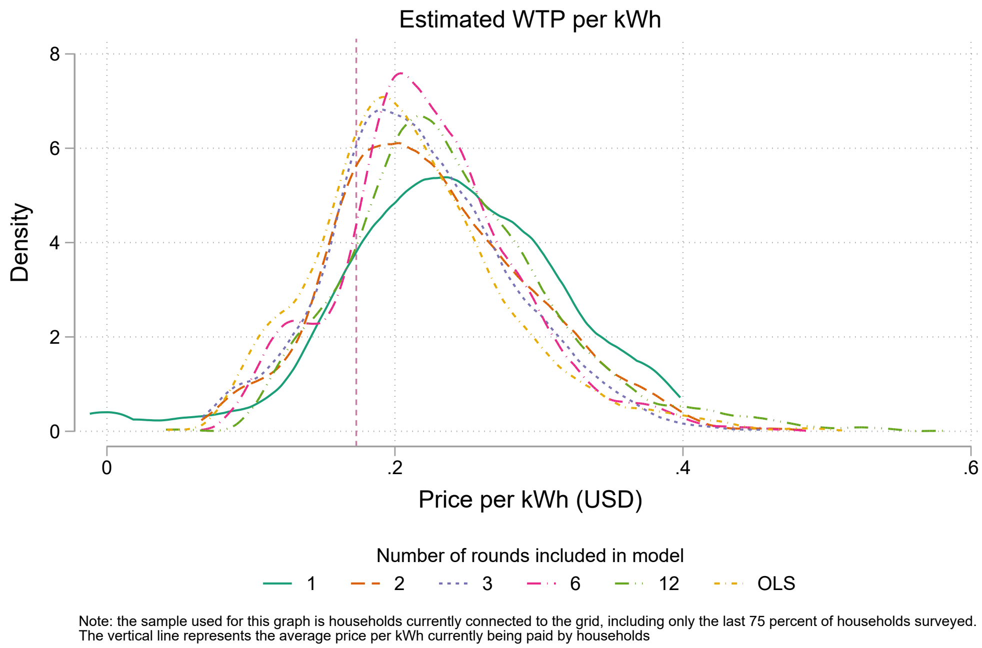

Figure B.10: WTP per kWh, households (cross-sectional), restricted to last 75% of surveys completed

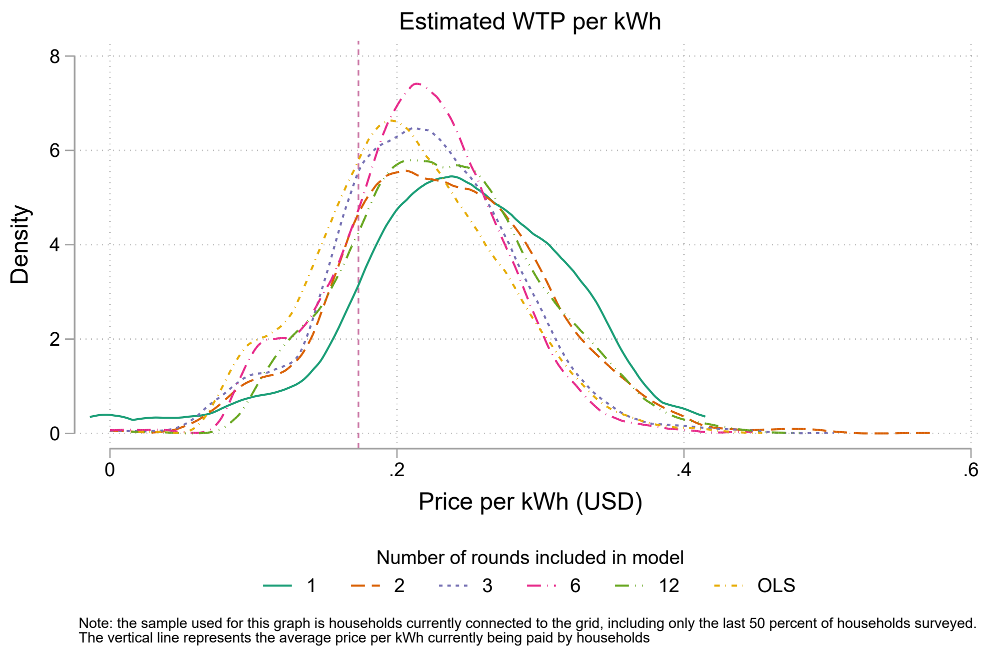

Figure B.11: WTP per kWh, households (cross-sectional), restricted to last 50% of surveys completed

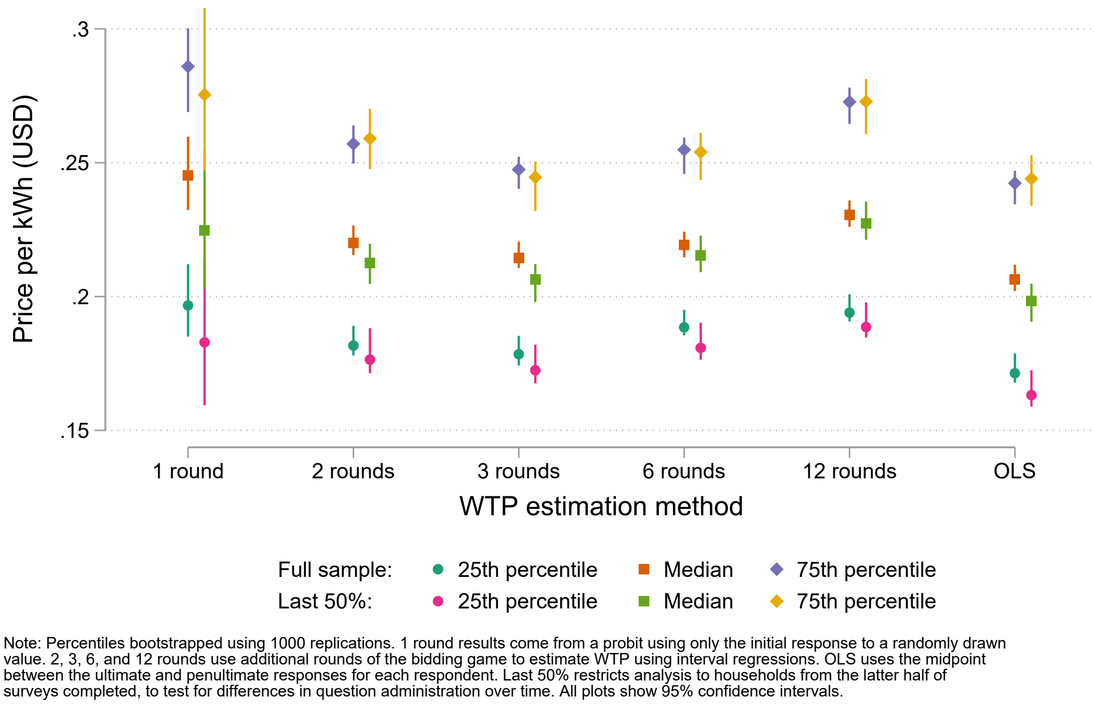

Figure B.12: Percentile comparisons of WTP estimates by method

Table B.10: Selection of electricity quality WTP papers and methods used

Authors	Location	Method	Scenario
Oseni (2017)	Nigeria	Double-bounded CV	Half power outages
Gunatilake *et al.* (2012)	India	Single-bounded CV	Good quality, uninterrupted power supply
Carlsson & Martinsson (2007)	Sweden	Open ended/Tobit	Nine different types of outages
Osiolo (2017)	Kenya	Open ended/Heckman two-step estimation	Quality levy
Taale & Kyeremeh (2016)	Ghana	Open ended/Tobit	Improved electricity services
Abdullah & Mariel (2010)	Kenya	Choice experiment	Frequency and duration of outages

C WTP scenario

The scenario presented to connected respondents was as follows (translated below into English):

We wish to measure with this question, the willingness of users to pay for quality electricity service.

We would like to know how much you appreciate better quality electricity service. No one is going to change your electricity rate as a result of what you say. However, if you value electricity enough, the government may decide to invest more in electricity and your rate may have to rise to pay for the investment.

Some people overestimate the amount they are willing to pay because they are frustrated with the current situation and want the investment to take place. If many respondents provide higher estimates, the government may set higher rates for electricity, which is beyond your ability to pay.

Similarly, some people underestimate the amount they are willing to pay because they are afraid of already paying too much or lying by thinking that the government will charge them less. But if enough people react this way, the government will think that electricity is not important to you and may not make additional investments in electricity improvement projects.

Also be mindful of your spending on alternative energy sources, such as candles and kerosene, and how your family's budget will be affected if you no longer have to buy as many alternatives to electricity.

You and your community will be at a disadvantage if you overestimate or underestimate your willingness to pay. So please try to be honest and just tell us what you are really capable of and willing to pay based on your income.

Taking into account your current expenses and the fact that your household now pays [monthly cost] FCFA and seeing that you suffer from power cuts.

Electricity use would be measured and you would be charged bi-monthly. Your bill would be [monthly cost], but you would likely be using more electricity than you are using right now.

Note that if you spend money to buy electricity from a source other than SENELEC or the Dealers, this amount will be offset against your monthly household expenses.

If you would receive "satisfactory electricity services" that would provide you with 24/7 electricity without power outages or brownouts, would you be willing to pay: [random initial price] CFA / Kwh?