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Economic Valuation of Electrical Service Reliability for Households' in Developing Country: A Censored Random Coefficient Model Approach

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ABSTRACT: The paper investigates the households' preference for electricity service reliability. Using a contingent valuation survey; we elicit Beninese urban households' willingness to pay (WTP) to avoid power outages. In the study respondents are asked to state their WTP for avoiding six different unplanned outages. We therefore apply a random parameter Tobit model on a temporal panel data since there is cross-sectional heterogeneity and a proportion of zero responses. Based on the estimations, we find that the preference for electricity service reliability among household is higher during night time and weekend days and depends positively on the duration of the outages. These results tend to validate the thesis that households preference for electricity service reliability strongly depends on leisure time.

Keywords: Outage, Multivariate censoring; Random coefficients; stated preferences; willingness to pay.
JEL Classifications: C15; C24; Q41

1. Introduction

One of the major problem concerning the energy policy managers rests on the electricity service reliability. It's then necessary to build appropriate standard for electricity service reliability. Indicators based on engineering standard reveal their limit as they ignore the consumer preference; consequence, the investments in capacity adjustment are inefficient and inadequate. Theoretically, this issue is analyzed through the cost for the consumers due to the interruption in the electricity supply. When the effect of electricity outage increases, the economic cost for the society increases as well and enhancing the electricity system reliability is subject to an increase in the investment and then the cost of the whole energy system. Ideally from a normative point of view, the reliability of the energy service should be optimized to the point where the sum of the economic cost of outage and the cost of the energy system is minimized (Munasinghe, 1980). Empirically, the electricity system reliability becomes one of the main challenges for developing countries (Alter and Syed, 2011). The good economic performances of this last decade and the improvement of living standard encouraged greater demand for electricity and put more pressure on the electricity demand management.

In order to implement appropriate policies to meet the demand for electricity service reliability to the end user, it is important to determine the cost that the consumer incurs because of the electricity outage. Most studies focus on the merchants users such as utilities and industries (Zuberi, 2012; Fisher-Vanden et *al*., 2012; Leahy and Tol, 2011; Balducci et *al*., 2002), However, in developing countries with an embryonic industry, households constitute one of the major electricity consumers. Their reliability requirement is therefore an important indicator in the decision to invest in the expansion of power generation capacity. This analysis is especially important for developing countries since they face chronic problems of outage or shortage (Linares and Rey, 2012). According to the literature, this may be related to the lack of information on the necessary cost to provide quality electricity service as well as the information on the expected demand for reliable service (Bliem, 2009; Sappington, 2005).

In the literature many studies try to assess the cost of outage to households. This task is further complicated that households generally do not produce merchant good or service with their electricity consumption. Four methods are generally used throughout the literature. The consumer surplus method (Sanghvi, 1982). It involves estimating of a household electricity demand function and to consider the consumer surplus loss due to the interruption of electricity supply as the outage cost to the household. Although intuitive, this method tends to underestimate the cost of outage (Sanghvi, 1982; Munasinghe and Gellerson, 1979).

Another method based on leisure opportunity cost is also used (Nooij et al., 2008; Nooij et al., 2007; Munasinghe, 1979, 1980). This method considers electricity as an essential input in the production of leisure; therefore, interruption in electricity supply depriving the household to produce and consume leisure at time t, generates a cost to the household; this cost is equivalent to the wage rate for the period corresponding to the outage. However, the model also contains significant limitations. These include the fact that the model implicitly assumes that workers can vary their working hours to balance their wage rate to the marginal value of their leisure. But the existence of statutory working times and restrictions imposed by the unions or the lack of sufficient opportunities are constraints to this flexibility. Workers are not working as much as they want, their wage rate will certainly overstate the value of their leisure time. Another weakness of this model is that in a situation where outage is regular, households already have an expectation of outage therefore when it occurs, its cost is much lower than the wage rate.

A third method based on revealed preference coexists with the previously presented methods. Sanghvi (1982), Bental and Ravid (1982), Matsukawa and Fujii (1994), assume that the consumer can choose different level of electricity supply reliability of and in these conditions it is important to analyze consumer preference for reliability taking into account its revealed preferences through its behavior on the market. The model developed by the authors, states that the preference for the reliability depends on the cost of the reinforcement equipment purchased by the consumer. According to the model, large electricity consumers are more attached to the reliability of electricity supply than small consumers. In other words, a consumer or household that maximizes his utility with a willingness to pay higher than the cost of purchasing the reinforcement equipment *i*, will choose and pay this reinforcement equipment to enjoy more reliable service; while households with lower willingness to pay will not procure the equipment. This method is costly in terms of collecting information on the characteristics of support or compensatory strategies facilities.

The last valuation method met in the literature, is that of contingent valuation approach or stated preferences (Carlsson and Martinsson, 2007, 2008). It is the most used method in the literature to estimate the outage costs; its effectiveness depends on the quality of the questionnaire as well as that of the survey.

Very few studies have focused on outage costs for households in African countries even though there is an acute need of electricity capacity building is in those countries. The attractiveness of the market is also linked to the price which is closely correlated with the quality of electricity service, this assumes that electricity service reliability estimation should be extended to all the different types of consumers including households (Reichl et *al*., 2008; Kidokoro, 2002).

The study uses a survey conducted in 2010 by the Center for Training and Research in Development. This survey included 624 households from the towns of Cotonou and Abomey-Calavi in Benin. An open-ended questionnaire format in adopted. This format has the advantage of producing very similar results to those which can be achieved in a real market (Carlsson and Martinsson, 2007; List and Gallet, 2001; Baliestreri et *al*., 2001). In particular, it asked the individual to give his maximum willingness to pay (WTP) to avoid electricity outage that occurs from a certain time for a certain period. The survey is only interested in unannounced outage with durations ranging from 1 hour to 8 hours per day; these characteristics of outage correspond to the type of outage implemented by the electricity company (Table 1). The data collected have a panel structure and are also identified as atemporal panel data, since the household WTP is observed for different types of electricity outage. This data structure is used in various applications in economics particularly, Cornick et *al*. (1994) use it to analyze household expenditures in the purchase of different types of milk; Skoufias (1993) uses it to analyze the time allocation of different household members through various activities and Carlsson and Martinsson (2007); Moeltner and Layton (2002); Beenstock et *al*. (1997) use it to estimate costs associated to various electricity outage.

Our study aims to estimate the cost of electricity outage for households. We therefore apply a random parameter Tobit model on an atemporal panel data. The choice of this model inspired from the work of Moeltner and Layton (2002) allows to account for the correlation between the cost of outage and the type of outage. Indeed, the literature abounds in works that argue that the cost or the inconvenience related to electricity outage depends on the duration, the frequency, the day, and the presence or not of compensatory strategies (Bliem, 2009; Carlsson and Martinsson, 2007, 2008; Moeltner and Layton, 2002).

Table 1. Outages Scenario

Scenario	Duration of Outage (hour)	Week day	Hour	My household is willing to pay
1	1	Working days	10 : 00	FCFA
2	4	Working days	10 : 00	FCFA
3	8	Working days	10 : 00	FCFA
4	8	Working days	18 : 00	FCFA
5	4	Weekend	10 :00	FCFA
6	8	Weekend	18 : 00	FCFA

The remainder of the paper is structured as follows; in the next section the theoretical model is presented, the third section presents the econometric model and the estimation strategy methodology; the fourth section discussed the results.

2. Theoretical Model

Our goal is to measure the monetary value that households associate with electricity outage. Let q the level of outage – the outage is measured as the time of electricity supply interruption –,q is then a scalar. Assume that the household has a utility function defined on the set of market goods that we represent by the vector x and on the good (bad) q.

$$U = U(x, q) \qquad (1)$$

We can derive from (1) an indirect utility function $V = V(p, q, y)$ where p is the vector of prices and y the household income. we assume that $U(x, q)$ is increasing quasi-concave in x, this implies that $V(p, q, y)$ satisfies the standard properties with regards to p and y[1]; $U(x, q)$ and $V(p, q, y)$ are all decreasing in q.

Let's assume that q varies from q^o to $q^{1;}$ the household utility varies then from $U^0 \equiv V(p, q^0, y)$ to $U^1 \equiv V(p, q^1, y)$, with $q^1 < q^0$ and $U^1 > U^0$. The monetary value associated with the reduction of the outage is represented by the Hicksian measurement of compensating variation C.

$$V(p, q^1, y - C) = V(p, q^0, y) \qquad [2]$$

In other words, the cost an outage of duration $\Delta q = q^1 - q^0$ imposes on the household is C which is also equal to the amount the household is willing to pay to avoid and electricity outage of duration Δq.

3. Econometric Model

The atemporal panel structure of the data raises two issues. On one hand, the data have a cross heterogeneity. Observations associated with a household are likely to be cross-sectional correlated. The stated WTP for a type of outage may depend on one expressed for a different type of outage. Errors are potentially correlated, in the presence of correlated errors, the use of OLS gives inefficient parameters and biased standard deviations. On the other hand, ''zero'' WTP simply means that the electricity outage cost to the household in zero and then the reliability of the electricity service doesn't matters for the household. In the presence of several ''zero'' answers, a high-dimensional probability Integrals issue arises. This suggests that the simulation techniques for joint probability terms, could be successfully employed in the estimation of such survey-generated, censored pooled regression models (Moeltner and Layton, 2002).

In our survey, we collect household WTP for various periods and various durations of outage. For simplicity reasons we call each feature of outage ''scenario''. Each response to a scenario is an observation of the dependent variable (WTP). We stipulate that the observations of the dependent variable are generated by a latent variable underlying and are censored at zero. The censoring in the

[1] $V(p, q, y)$ is homogeneous of degree zero in p and y, increasing in y, none decreasing in p and quasi-convex in p (Mas-Colell et *al.* 1995)

context of this model is of great importance in the sense that the ''zero'' WTP is a valid response. In order to account for the ''zero'' and the cross heterogeneity, we use a censored model which general form can be written as :

$$WTP_{is}^{*} = f(x_{is}, \beta, \varepsilon_{is}) \qquad \varepsilon_{ij} \rightarrow N[0, \sigma^2] \qquad (3)$$
$$WTP_{is} = max\{0, lnWTP_{is}^{*}\},$$

Where, WTP_{is}^{*} is the latent variable of household's i WTP with respect to scenario s, x_{is} represents all the characteristics of the scenarios. β is the vector of parameters; WTP_{is} is the observed value of the CAP for household i for scenario s and ε_{is} represents the term of error.

In general, each respond depends on the specific characteristics of the household and the scenario involved. However the inclusion of observed attributes of the respondents in our model may result in omitted variable problems, because they are likely to be correlated with unobserved component of the errors (Wooldridge, 2002). For example, in the context of our study, the estimated cost associated with a given outage scenario may well depends on household characteristics that cannot be captured during a survey, such as some details on the use of electricity, or the sensitivity of household members when outage occurs.

These unobserved variables may be correlated with the observed characteristics of households such as demand at peak times etc. for these reasons as Moeltner and Layton (2002) and Carlsson and Martisson (2007), we consider only the characteristics of the scenarios as explanatory variables in our model. We assume that the characteristics of the scenarios variously affect households; we link unit-specific observations by allowing parameter sets associated with a given respondent to vary randomly around a common mean-coefficient vector. This deviation parameter is then assumed to capture unobserved preference heterogeneity. We assume that the randomly distributed parameters are constant across the valuation questions for each respondent. This reflects an underlying assumption of stable preference structure for each respondent when answering the set of valuation questions. In addition, we assume that the intercept is randomly distributed, which is the equivalent of a random effects panel data model (Carlsson and Martisson, 2007).

The estimation of (3) with maximum likelihood estimators involves a high-dimensional probability Integrals and the use of numerical integrals approximation method. In our case, after checking for the sensitivity of the quadrature approximation, we use the Gauss-Hermite quadrature approximation (Stata, 2005; Lui and Pierce, 1994). We estimate the model under the STATA procedure. The simulated joint probabilities have the desired properties; with unbiased estimated probabilities and continuity as well as differentiation in the parameters.

4. Results

In Table 2, we present the descriptive statistics of the WTP responses to the outage scenario. The outage cost (WTP) varies with regard to the outage occurrence. When it occurs during weekend days, the average WTP of households is the double of what they are willing to pay if it occurs rather a working days (approximately 800 FCFA and 400 FCFA respectively). From this point, we can conclude that the outage cost of electricity for households during the weekend is much higher than the one incurred working days.

This can be explained by the fact that households are more present at home during the weekend and can therefore engage in electricity consuming activities; any power outage that occurs at these times inflicted enormous costs to households.

The average households' WTP to avoid outage during night time is more than the double of its willingness to pay to avoid day time outage (WTP of FCFA 831 and FCFA 381 respectively). During day time, households are generally out of home and therefore do not suffer huge inconveniences due to outage. 100% of the household surveyed declared they use electricity mainly for lighting; yet, the lighting is proven necessary at night time, therefore it is expected that the cost associated with electricity supply interruption during night time be high.

In general, the cost to households associated with electricity supply interruption during the weekend is much higher than its counterpart on working days. The figure also gives evidence that households are more susceptible to electricity outage when it occurs at night time.

Table 2. Willingness to pay[2]

By outage day

Day	Weekend			Working days		
	Mean	Min	Max	Mean	Min	Max
WTP	796,258	0	8000	398,8018	0	5000

By day time

Period	Day time			Night		
	Mean	Min	Max	Mean	Min	Max
WTP	381,3366	0	6000	831,1884	0	8000

By day and period of day

Day	Working days		Weekend	
Period	Night	Day time	Night	Day time
CAP	712,425	294,2607	949,9518	642,5643

Source: Author

All the parameters are significant at 1% (Table 3). The coefficients are positive as expected, the outage costs are on average higher during the weekend (as indicated by the variable *week* that takes the value 1 for weekend day and 0 for working days), and during night time, as indicated by the variable *night* The outage cost also increases with the outage duration (*ldur*). The day variable *week* has a stronger effect on outage cost to the household than the night variable. In other words, households are more affected by power outages that occur during the weekend than those occurring during night time. It is therefore expected that households have a stronger preference for electricity service reliability during the weekend. The positive value of the constant indicates that the expected cost of a momentary outage is not zero.

The significance of ρ and then of σ_u^2 indicates that a constant parameter model would be a misspecification; the estimated parameters vary considerably on the cross units. The likelihood ratio test (LRT) rejects the null hypothesis that all the elements in Δ are zero. This, in turn, implies that our assumption of correlated error terms within cross-sectional units holds.

The significance of the variance-covariance matrix of the coefficients allows for insights beyond those provided by a model with constant parameters. The significance of the variance-covariance matrix implies in particular that there is considerable heterogeneity in the expected outage costs. The significance of the elements of the variance-covariance matrix shows in fact that there are households who experience outage costs higher or lower than the overall average. This is the case for example of a household who loves sports and who misses the final of the football world Cup due to electricity outage, while over the same period another household interested in a program that starts just after the football game will not suffer the same cost.

Table 3. Estimation of Willingness to Pay

Variables	Coefficients	P-value
Ldur	1,2651*	0,000
Week	1,3809*	0,000
Night	0,8180*	0,000
const	1,9669*	0,000
σ_u^2	1,7730*	0,000
σ_e^2	2,0733*	0,000
ρ	0,4223*	0,000
LRT $\sigma_u^2 = 0$ chibar2(01)=793,81 Prob>=chibar2=0,000		

*significant at 1%
Source: Author

[2] Divided by 500 to obtain the value in US$

Information on cross-effects of outage features can be gained by examining the off- diagonal elements of Δ (Table 4). Most of these elements are a negative. When we take for example, *week* and *ldur*, the coefficient is negative this suggests that a household that suffers a high outage cost during the weekend will undergo a decreasing marginal cost of outage cost as the outage lasts for long time. This result can be explained by the ability of households to adapt to electricity outage or to replace the electricity dependent activities by none electricity dependent activities. For *night* and *week*, the coefficient is also negative; this suggests that a household that suffers a high cost of electricity interruption during night time, will incur a decreasing marginal outage cost as the outage shift from weekend to working days.

Table 4. Variance-covariance Matrice

	ldur	week	night	Const
Ldur	.00380406			
Week	-.00042306	.00637391		
Night	-.0030579	-.00113428	.00878461	
Const	-.0046331	-.00117834	.00202142	.01301605

Source: Author

Starting from the results of Table 2 and assuming as Moeltner and Layton, (2002) that,

$$\left(WTP_s \middle| x_s \widehat{\overline{\beta}}\right) = \overline{WTP_s} \qquad (4)$$

With the expected latent WTP in logarithm and $\widehat{\overline{\beta}}$ = the vector of the estimated parameters $\overline{\beta}$, the predicted average outage costs are as follow (Table 5).

Table 5. Predicted Average Outage Cost

Outage type	**Predicted WTP**	**Predicted WTP (US$)**
Working days, outage during day time		
Duration (hour)		
1*	109 FCFA	0,21
2	179 FCFA	0,35
3	210 FCFA	0,42
4*	260 FCFA	0,52
5	323 FCFA	0,64
6	386 FCFA	0,77
7	450 FCFA	0,9
8*	513 FCFA	1,02
Weekend, outage during day time*		
Duration : 1 hour	642 FCFA	1,28
Weekend, outage during night time*		
Duration : 8 hours	950 FCFA	1,9

Source : Author * Sample Statistic

4. Conclusion

The study investigates households' preference for electricity service reliability. The study elicits Beninese households' willingness to pay to avoid six different types of electricity power outage. We therefore apply a random parameter Tobit model since there is cross-sectional heterogeneity and a proportion of zero responses. Based on the estimations, we find that households state a preference for electricity service reliability during the weekend and during night time irrespective to the day. However the households state a higher preference for electricity service reliability during the weekend than the night time of working days. This result comes to validate Munasinghe (1979, 1980) thesis which suggests to approximate the outage cost, to household, to the leisure opportunity cost. The results also suggest that the electricity price system, to reflect consumer reliability requirements, must be sufficiently flexible and account for days and day periods or time.

From this study, the alleviation of the chronic electricity outage in developing countries includes the implementation of pricing policies, where the different end users are supposed to choose the couple (reliability level – price) according to their preference for electricity service reliability. Price policy as such will, on one side, help to mobilize from the consumers the necessary financing to improve the electricity generating system at their preferred reliability level and, on the other side, to improve the power system planning and operating.

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