Estimation of Households' and Businesses' Willingness to Pay for Improved Reliability of Electricity Supply in Nepal

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ABSTRACT

For the decade prior to 2016 Nepal suffered from the worst electricity shortages in South Asia. During this period load shedding occurred for up to 18 hours a day when hydropower generation is low. This research uses parametric and non-parametric models to estimate households' and businesses' willingness to pay (WTP) for improved reliability of electricity services in Nepal. A contingent valuation (CV) survey was completed by 1,800 households and 590 businesses. The parametric models are estimated using Logit regressions. The median, Turnbull and the Kriström mean estimation approach were used for the non-parametric estimations. Both households and businesses are willing to pay more to get from a 50% reduction to a complete elimination of outages than they are willing to pay to get from their current situation to a 50% reduction in outages. This difference in the estimates of the WTP for these two options is even more important in the case of businesses than for households. It is estimated that the annual benefit in 2017 from improving the reliability of the electricity service would be approximately US$324 million with a present value over 20 years of between US$2 and 3.8 billion.

Keywords: Nepal, willingness to pay, electricity outage, contingent valuation, non-parametric methods estimation Electricity.

Jel Classification: D61, Q41

1. Introduction

For at least 25 years, Nepali consumers have had to grapple with indiscriminate power outages and an overall poor quality of electricity services. [1] A situation that was not good was made much worse with the major earthquakes that Nepal suffered in 2015 which destroyed a significant amount of the electricity transmission system in the country. The inadequate management of the public electricity utility has led to large commercial losses which has resulted in financial stress for the utility. Power outages increase production costs and increase the operating uncertainty that enterprises face. The cuts in power supply have led to production losses that last beyond the duration of the outage. "Production losses arise from reduced output, spoilage of in-process materials and even damage to machinery, all translating into financial losses." (Hashemi, at al., 2018). In 2015, the World Economic Forum ranked the quality of Nepal's electricity supply as 136th out of a total of 144 countries. A 2011 study identified Nepal as having the most depressed power capacity and load shedding problem in the region, meeting a little more than half of estimated demand (The World Bank, 2011).

Due to the poor quality of the electricity service, Nepal has amongst the lowest per capita use of electricity in the world. The World Bank estimated in 2011 that the annual per capita electricity use in Nepal is only 106 kwh, which is one-sixth of that in India, Nepal's neighbour to the south and one-thirtieth of the per capita electricity use in China. Electricity generation for the Nepal power grid is mostly from run-of-the-river hydropower but, during the dry winter months, when hydropower generation is low, there is load shedding of up to 18 hours per day. On-grid system losses are currently estimated at 26 percent, the highest rate in the region. Approximately 30 percent of the residents of Nepal are without access to electricity, contributing to a lack of economic growth, particularly in the rural areas. The low availability of electricity creates significant costs for businesses because they are forced to invest in expensive back up generation that runs on either high cost imported fuel or on solar photovoltaic systems, batteries and inverters. [2]

The purpose of this study is to assess the willingness of households and businesses to pay more than they are currently paying for a supply of electrical energy that has fewer scheduled and unscheduled outages and a more stable voltage. To estimate these parameters, a contingent valuation method (CVM) is employed using both non-parametric and parametric binary/logistic regression analyses. The remainder of the paper is structured as follows. Section 2 describes the methodology used in the study, the data, the conceptual framework and the empirical model. Section 3 provides a summary of the basic statistics. Section 4 contains the results and discussion and Section 5 provides the conclusions and policy implications.

[1] World Economic Forum, http://reports.weforum.org/global-competitiveness-report-2014-2015/economies/#economy=NPL
[2] SARI/Energy, Nepal Energy Sector Overview

2. Methodology

A number of methodological approaches have been developed to measure an individual's willingness to pay for reliable public goods and services (Sanghvi, 1983; Tollefson et al., 1994; Green et al., 1998; Billinton and Pandey, 1999; Chowdhury et al., 2004; Schläpfer and Schmitt, 2007; Flores and Strong, 2007; Zachariadis and Poullikkas, 2012; Küfeoğlu and Lehtonen, 2015, Cohen et al., 2016). The stated preference approach measures incremental or marginal improvements in the non-market value of individuals' preferences for electricity service improvements based on hypothetical scenarios through surveys (Mitchell and Carson, 1989; Boxall et al., 1996; Adamowicz et al., 1998; Hensher et al., 2005 b; Carson and Hanemann, 2005). The stated preference approach most frequently employed has been the CVM. It basically expresses in monetary terms the change in economic welfare arising from a change in the quality or quantity of services. This approach typically involves the measurement of the consumer valuation of predefined changes in service levels (Rehn, 2003; Wiser, 2003; Atkinson et al., 2004; Carlsson and Martinsson, 2006; Carlsson and Martinsson, 2007; Kateregga, 2009; Hoyos and Mariel, 2010, Ozbaflı and Jenkins, 2015).

The random utility model (RUM) forms the basis of the empirical analysis of limited dependent variables and is the common theoretical framework for the CVM method. Under the RUM framework, we cannot obtain perfect information nor observe the complete information in the utility function. Thus, the random utility U_{ji} of alternative i perceived by individual j is partitioned into two components; a deterministic V_{ji} and a random component ε_{ji} as:

$$U_{ji} = V_{ji} + \varepsilon_{ji} \tag{1}$$

The indirect deterministic utility function in CVM is defined by V = V (P_x, R, Y, A_j), where P_X denotes the price vector for all the other goods or services (X) consumed by businesses and households, R is the level of reliability in the electricity supply, Y is the individual's income, and A_j is the characteristic vector of individual j. Individuals are asked whether or not they are willing to pay an additional cost to secure a reliability improvement in the electricity supply. A "yes" response is denoted as "y = 1" while "no" is denoted as "n = 0". Equation (1) is expressed in terms of the probability of an individual choosing "yes" is given as equation (2) and "no" as equation (3).

$$P_{jy} = P(\varepsilon_{jy} - \varepsilon_{jn} < V_{jn} - V_{jy}) \tag{2}$$

$$P_{jn} = P(\varepsilon_{jn} - \varepsilon_{jy} < V_{jy} - V_{jn}) \tag{3}$$

An assumption is made about the distribution of the random errors. They are assumed to be independent and identically distributed (IID) with a mean of zero and Extreme Value Type I distributed.

Define $\eta = \varepsilon_{jy} - \varepsilon_{jn}$, and let $F_\eta(.)$ be the cumulative distribution function of η. Then

$P_{jy} = F_{\eta}(\Delta V)$, where $\Delta V = V_{jn} - V_{jy}$ (4)

The probability that the individual is willing to pay is then given by:

$P_{jy} = 1 - P_{jn}$

Then P_{jy} can be rewritten in terms of WTP* as:

$P_{jy} = P(WTP^* > B) = 1 - GWTP^*(B),$ (5)

Let WTP^* be the individual's maximum WTP for the reliability improvement and B is the bid offered to the respondent. Then $GWTP^*$ (.) is the cumulative distribution function of WTP^*.

2.1. Description of the Study Area and Data

Nepal is a landlocked country with a population of 26.5 million people. It is divided into three distinct zones. The mountains (Himalayas) in the north, the Tarai (the plains) in the south and the hills between. The Tarai region is home to half of the population while the hills are home to 43 percent of the population with the balance (7 percent) living in the mountains. Per capita income in the country was \$862 in 2016. [3] The Nepal living standard surveys (NLSS 2010/2011) estimate that 25.2 percent of the population were living below the poverty line of \$1.28 per day (CBS, 2016). Of the total population, 82.9 percent people live in rural areas. Agriculture is the mainstay of the economy accounting for one third of gross domestic product (GDP) [4].

Energy sources in Nepal can be divided in three categories; traditional (fuel wood, agriculture residues and animal dung), commercial (fossil fuels and electricity) and alternative (new and renewables). Nepal has no significant reserves of fossil fuel resources. All petroleum products and over 75 percent of coal are imported from India (WECS, 2010). Natural gas is not used in the country. Yet, only 1percent of the electricity potential of hydropower and other renewable energy resources has been developed (NEA, 2014).

In 2017, a total of 65,203 businesses were connected to the National Electrical Authority in Nepal. Out of this total, 18,860 were commercial businesses and 46,343 were classified as industrial businesses. In addition, there were a total of 3,080,252 residential type connections to the NEA including

[3] the average exchange rate of 106 Rs/US dollar for 2016 (Central Bank of the Nepal, https://www.nrb.org.np/ accessed 20 September 2017)

[4] Nepal is divided into 14 zones and 75 districts. These administrative districts are divided into smaller units, called village development committees (VDCs) and municipalities. The VDCs are rural areas and municipalities are urban areas. Currently, there are 3,915 VDCs and 58 municipalities. These 58 municipalities include 1 metropolitan city (Kathmandu, the capital city of Nepal), 4 sub-metropolises and 53 municipalities (CBS, 2012).

3,060,995 households and 19,257 non-commercial entities (NEA, 2017). In 2017, the residential and business sectors consumed 48 percent and 43 percent respectively of the total electricity supplied (NEA 2017)

A questionnaire was developed with respect to design objectives and statistical efficiency, (Bose and Shukla, 2001; CIE, 2001; KPMG, 2003; Hensher et al., 2005a; RIC, 2005; Carlsson and Martinsson, 2007; Carlsson and Martinsson, 2008, Carlsson et al., 2011, Hensher et al., 2014). The questionnaire was organized into seven main sections; quality control, current electricity service, electricity consumption pattern, WTP for an improved system (a CVM question), preparatory actions (averting behaviour), averting expenditures, and business or household characteristics. The survey asks attitudinal questions regarding the respondent’s current electricity service in order to reveal the respondents' attitudes towards the electricity system overall, as well as information on load shedding and on tariff variations. Perceived quality of service has been found to have a positive impact on WTP. In addition to the attitudinal questions, the survey includes questions on the duration and frequency of interruptions (planned and unplanned) as perceived by the respondents. WTP for a reliable electricity supply is expected to be related, among other things, to the household's dependence on electricity. Hence, some questions were asked to determine the level of dependency on electricity. Also, some questions explore what actions households take in preparation for outages.

The CVM question was one in which a hypothetical improved system was defined. Using a bidding format and cheap talk, the respondents were asked about their WTP for a system that would ensure a reliable power supply (Table 2). Cheap talk was used to reduce hypothetical bias (Cummings and Taylor, 1999; List, 2001; Brown et al., 2003; Bulte et al., 2005; Aadland and Caplan, 2006). In order to have a reliable electricity power supply, respondents would pay their monthly electricity bill plus a premium on the bill to cover the total monthly cost of the improved system. Finally, the questionnaire collected data on business and household characteristics.

Table 1. Willingness to pay for a reduced number of outages

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

Some people over-estimate the amount they are willing to pay because they are frustrated by the current situation and want the investment to happen. If many respondents provide higher estimates, then the government could set a higher tariff for electricity which is beyond your ability to pay.

Likewise, some people under-estimate the amount that they are willing to pay because they are concerned that they already pay too much, or they lie thinking that the government will charge them less. But, if enough people respond this way, the government will think that electricity is not important to you and may not make additional investments in electricity improvement projects.

Please also be aware of your expenses on alternative energy sources, such as candles and kerosene, and how your family's budget will be affected if you no longer have to purchase so many alternatives to electricity.
Your VDC or Municipality will be at a disadvantage whether you over-estimate or under-estimate your willingness to pay. So, please try to be honest and tell us only what you are truly able and willing to pay based on your income.

	Bids
a) Would you be willing to pay the following additional amount for 50% less outages per week? ** b) Would you be willing to pay the following additional amount for No outages per week? ***	1. Would not go for the improved system 2. 10% of current bill* 3. 20% of current bill 4. 30% of current bill 5. 40% of current bill 6. 50% of current bill 7. 60% of current bill 8. 70% of current bill 9. 80% of current bill 10. 90% of current bill 11. 100% of current bill 12. Max WTP …. % of current bill

* Current bill is determined by computer from the highest monthly payment bill.
**If the respondent chooses to pay an additional amount for 50% less outages per week then the base figure is calculated as current bill* random value (Bids).
*** If the respondent chooses to pay an additional amount for No outages per week then the base figure is calculated as current bill*random value +WTP for 50% less outages per week.

In the case of determining the respondent's maximum willingness to pay for a 50 percent and a 100 percent decrease in outages, the initial bid was created as a random amount in Nepalese Rupees (Rs) from zero to 100 percent of the monthly electricity bill. If the respondent agreed that they would pay this initial amount, (a "yes" response), then they would be asked if they were willing to increase their payment in steps of 10 percent of their electricity bill until the response is "no". If the response to the initial random bid was a "no", then this initial bid was decreased in steps of 10 percent of the respondent's electricity bill until the respondent said "yes" to the proposed amount.

A pre-test of the questionnaires was carried out using a sample of urban, peri-urban and rural households and businesses located within and around the Kathmandu valley. A total of 40 households and 10 businesses were interviewed for the pre-test. A pilot study was conducted after the sampling plan and the household selection method was finalized. The main purpose of the pilot study was to test the electronic version of the questionnaire along with the sampling method and the GIS-based data collection process. A total of 150 households and 50 businesses were interviewed for the pilot testing.

It was envisaged that the pilot testing would lead to the finalization of the questionnaire along with all other survey related matters leading to the main survey.

The main survey was conducted from the beginning of October 2016 to the end of April 2017. Wards were selected for both Municipalities and village development committees (VDCs) using a random selection method. The starting point was selected randomly within the border of each ward. Each ward was divided into predefined grids or squares using satellite imagery and numbered. After this process, the selection was made randomly from the numbered squares or buildings. The Computer Aided Personal Interviews (CAPI) questionnaire was carried out with households and businesses who were buying electricity from the Nepal Electricity Authority (NEA). In total, 1,800 households and 590 businesses provided completed questionnaires. The overall usable response rate for the WTP survey conducted amongst households was 86 percent which means that 2,080 approaches were made to households. For businesses, the response rate was 36 percent which means that 1,621businesses were approached in order to obtain 590 fully completed questionnaires. The final survey data included the sample of 270, 222 and 98 small, medium and large businesses respectively.

3. Data collection and preliminary analysis

Males made up 52.9 percent and females 47.1 percent of the sample respondents. The interviews were carried out whenever possible with the head of the household or a knowledgeable adult from the household.. In Nepal, household heads are more likely to be male than female. The residences of 44.4 percent of respondents were in VDC districts. Of the 1,800 respondents, 2.2 percent live in the mountains, 57.7 percent in the hills and 40.1 in the Terai. In our sample, the illiteracy rate in Nepal is 20.1 percent. Among respondents with a formal education, 7.3 percent finished primary school, 7.7 percent finished high school, 7.3 percent graduated from a 4-year university program and 0.3 percent completed a professional degree. The sample contained a high percentage (56.8 percent) of families with school age children. The monthly reported household income of 60 percent of respondents was between Rs 10,000 and Rs 40,000 ($94 - $377) with 7 percent having incomes below Rs 10,000 ($94) and 33 percent earning above Rs 40,000 ($377) per month. In terms of caste, a total of 38.4 percent of the respondents were Brahman. NEA provided 85.9 percent of own metered connections while landlords provided 11.1 percent of sub-metered connections. The remaining 3 percent of households had informal connections provided by neighbours or relatives. Of the total, 77.2 percent of respondents paid monthly to NEA for their electricity usage. On average, households paid Rs 601 ($5.67) per month for their electricity. Among the respondents who stated that they experienced a moderate number of failures, many also stated that these failures contributed to difficulties in studying and use of fewer leisure devices. A very high percentage (71.7 percent) of the respondents experienced brownouts that occurred on average 11.25 times per year. Of the total number of respondents, 66.3 percent reported that brownouts mainly occurred during the evenings and nights.

Industry/manufacturing establishments made up 57.6 percent of the sample while the remaining 42.4 percent were members of the service sector. The annual turnover for businesses was on average Rs 203,348,000 ($1,918,378). The average number of permanent workers per business was approximately 71. In terms of location, 80 percent of businesses resided in municipality districts. In terms of regions, 25.9 percent were from the Hill regions and 74.1 percent from the Terai. NEA provided 89 percent of own metered connections. Landlords provided 11 percent of sub-meter and informal connections of which the main provider was the NEA. Approximately 99.5 percent of respondents paid for their electricity usage based on the meter/sub-meter readings. In terms of paying for their electricity, 88.8 percent of business respondents paid NEA for their monthly usage. About 46 percent of respondents used 400 V three phase electricity supply in their business. On average, businesses pay Rs 296,600 ($2,798) per month for their electricity. The majority of respondents have experienced electricity outages resulting in losses of production, idle periods and loss of competitiveness due to the higher electricity cost. They estimated that if they had access to a 24/7 electricity supply they could increase their annual turnover by 15.17 percent. A very high percentage of the respondents (64.4 percent) stated that they experienced brownouts on average about 3 days per year, of which 39.8 percent occurred in the afternoon. Furthermore, 13.6 percent of respondents experienced surges in their electricity on average 2.14 times per year. Out of the total number of respondents, 9.8 percent stated that the voltage surges caused damage to their equipment/appliances with an average cost per year of Rs 86,782 ($819).

During periods of power outages about 47 percent of households used torch lights or emergency lights to provide light whenever power outages occur. The next most used alternative source of light was candles (20.2 percent). The most used alternative sources of electricity in industry/manufacturing establishments were inverters and battery sets (72.5 percent) and electric generators (68.3 percent).

3.1 Empirical Model

A. Parametric Method

The binomial logit model is a parametric approach to determine the WTP of respondents using the dichotomous choice valuation format (Bishop and Heberlein, 1979; Hanemann, 1984). For econometric estimation, assume WTP^* of individual j has the following form:

$$WTP^*{}_j = \beta X_j + \omega_j \quad (6)$$

where X_j are the explanatory variables, β are the coefficients of the explanatory variables and ω_j are the random errors. As the ω_j are assumed to have the standard logistic distribution, then the expected probabilities for an individual choosing alternative y can be formulated as:

$$P_{jy} = \frac{exp^{(V_{jy}-V_{jn})}}{1+ exp^{(V_{jy}-V_{jn})}} \quad (7)$$

B. Non-Parametric Method

The non-parametric approach is another way of estimating the WTP of the discrete choice contingent valuation methods. This approach removes the distribution assumption to derive the WTP. Two non-parametric estimation approaches are those proposed by Turnbull (1976) and Kriström (1990). Non-parametric approaches are based on the discrete response survey format where the individuals indicate whether they accept paying the additional cost for the reliability improvement or not. In these models, different amounts of additional payments or bids (B_j) are offered to N different individuals. If the number of "yes" answers to B_j are presented as Y_j , then the probability of those in the sample being willing to pay B_j is estimated as $P_j = Y_j/N_j$. This probability will be expected to be monotonically non-increasing sequences of proportions to construct a survival function. The Kriström mean WTP is interpolated between each interval to describe the area under the survivor function. By using the lower and upper bounds of the intervals, the Turnbull estimator can also be used to evaluate the average mean WTP.

The Turnbull Lower Bound Mean (LBM) estimate is expressed:

$$\text{LBM (Turnbull)} = p_1 B_1 + \sum_{i=2}^{m} p_j (B_i - B_{i-1}) \quad (8)$$

The variance of the LBM:

$$Variance\ (LBM) = \sum_{j=1}^{m} \frac{p_j(1 - p_j)\ (B_j - B_{j-1})^2}{N} \quad (9)$$

The Turnbull Upper Bound Mean (UBM) is expressed as:

$$\text{UBM (Turnbull)} = p_1 B_1 + \sum_{i=2}^{m} p_j (B_{i+1} - B_i) \quad (10)$$

The Kriström mean is expressed as:

$$\text{Kriström mean} = LBM + \left(\frac{1}{2}\right) B_0 (1 - p_0) + \sum_{i=2}^{m} (1/\ 2)\ |\mathrm{p}_i - \mathrm{p}_{i-1}| (B_i - B_{i-1}) + (\frac{1}{2}) p_k (B^* - B_K) \quad (11)$$

B^* is the estimated bid price where p falls to zero.

4. Results and discussion

In order to carry out the non-parametric estimation of the average WTP for households and businesses, there is a need to create a ranking of the frequency of the bid responses to progressively higher values of the WTP. For each bid B_j we used the "YES" data (the lower limits on WTP) for both the 50 percent and 100 percent fewer outage situations to calculate the cumulative number and proportion, p_j, of the "YES" responses. These results are reported in Tables 2 and 3.

Table 2. Proportion of YES Answers (Household)

	lower limits on WTP for 50% less outages				lower limits on WTP for 100% less outages			
N=1800								
j	Bid as % of current bill	Lower bound (YES)	Cumulative number of YES	Proportion of Yes answer (pj)	Bid as % of current bill	Lower bound (YES)	Cumulative number of YES	Proportion of Yes answer (pj)
0	0	326	1,800		0	82	1,800	
1	10	373	1,474	81,9%	10	446	1,718	95,4%
2	20	319	1,101	61,2%	20	346	1,272	70,7%
3	30	232	782	43,4%	30	236	926	51,4%
4	40	161	550	30,6%	40	177	690	38,3%
5	50	120	389	21,6%	50	132	513	28,5%
6	60	74	269	14,9%	60	92	381	21,2%
7	70	40	195	10,8%	70	82	289	16,1%
8	80	38	155	8,6%	80	54	207	11,5%
9	90	39	117	6,5%	90	50	153	8,5%
10	100	36	78	4,3%	100	45	103	5,7%
11	110	20	42	2,3%	110	19	58	3,2%
12	120	1	22	1,2%	120	4	39	2,2%
13	130	8	21	1,2%	130	7	35	1,9%
14	140	2	13	0,7%	140	2	28	1,6%
15	150	1	11	0,6%	150	2	26	1,4%
16	160	3	10	0,6%	160	3	24	1,3%
17	170	2	7	0,4%	170	4	21	1,2%
18	190	1	5	0,3%	190	4	17	0,9%
19	200	2	4	0,2%	200	3	13	0,7%
20	240	1	2	0,1%	210	1	10	0,6%
21	250	1	1	0,1%	220	3	9	0,5%
22					250	3	6	0,3%
23					430	2	3	0,2%
24					500	1	1	0,1%

The median estimation of the WTP provides a lower bound value to the overall WTP (Hanemann, 1989; Haab and McConnell, 1997; 1999). In Table 6, row 1, the reported estimates of the median WTP for a 50% reduction in outages by households is found to be 26.30 percent of their current electricity bill. The median household is willing to pay a further 31.30 percent of the current electricity bill for another 50 percent reduction in outages. The median households are willing to pay at least 57.60 percent more than their current bill to completely eliminate the problem of electricity outages.

Table 3. Proportion of YES Answers (Business)

	lower limits on WTP for 50% less outages				lower limits on WTP for 100% less outages			
N=590								
j	Bid as % of current bill	Lower bound (YES)	Cumulative number of YES	Proportion of Yes answer (pj)	Bid as % of current bill	Lower bound (YES)	Cumulative number of YES	Proportion of Yes answer (pj)
0	0	114	590		0	15	590	
1	10	181	476	80.7%	10	77	575	97.5%
2	20	108	295	50.0%	20	102	498	84.4%
3	30	69	187	31.7%	30	86	396	67.1%
4	40	46	118	20.0%	40	65	310	52.5%
5	50	28	72	12.2%	50	59	245	41.5%
6	60	14	44	7.5%	60	46	186	31.5%
7	70	8	30	5.1%	70	34	140	23.7%
8	80	4	22	3.7%	80	32	106	18.0%
9	90	5	18	3.1%	90	30	74	12.5%
10	100	10	13	2.2%	100	21	44	7.5%
11	110	1	3	0.5%	110	7	23	3.9%
12	120	1	2	0.3%	120	4	16	2.7%
13	330	1	1	0.2%	140	1	12	2.0%
14					150	4	11	1.9%
15					180	1	7	1.2%
16					200	1	6	1.0%
17					280	1	5	0.8%
18					330	1	4	0.7%
19					500	1	3	0.5%
20					530	1	2	0.3%

Turnbull lower and upper bound mean estimates can be made for the WTP by households for a 50 percent reduction in electricity outages and also for a complete elimination of the electricity outages (100 percent reduction). The Turnbull lower bound estimate (Table 6, row2) of the WTP for a 50 percent reduction is found to be 29.22 percent of the current electricity bill. For the incremental improvement from a 50 percent reduction in outages to a 100 percent reduction in outages households are willing to pay a further 34.84 percent of their current electricity bill. On average, households are willing to pay at least 64.06 percent more than their current bill to eliminate the problem of electricity outages. The average WTP for the Turnbull upper bound estimate for a 50 percent reduction in outages is 39.26 percent of the current bill (Table 6, row 4). The incremental WTP is 44.37 percent if it would be possible to eliminate all outages. The combined WTP to eliminate all electricity outages is an increase of 83.63 percent of the current electricity bill of households.

The average WTP from the Kriström mean estimate for a 50 percent reduction in outages is 34.24 percent of the current bill. The households' incremental WTP in order to eliminate all outages is equal to 40.44 percent of their current electricity bills. The combined WTP to eliminate all electricity outages is 74.68 percent of the current electricity bills of households (Table 6, row 3).

For businesses, (Table 6, row 6) the median WTP of a 50 percent reduction in outages is 20 percent of their current bills. Moreover, the incremental median WTP if estimated for the move from a 50 percent reduction in outages to a 100 percent reduction in outages. The median business is willing to pay a further 42.30 percent of their current electricity bill to reduce the outages by a further 50 percent. Hence, the median business is willing to pay at least 62.30 percent to completely eliminate the outages.

The Turnbull lower bound estimate of the WTP by businesses for a 50 percent reduction is found to be 22.05 percent of the current electricity bill. The incremental WTP to move from the 50 percent reduction to a 100 percent reduction in outages is estimated to be a further 49.51 percent of the current electricity bill. In total, businesses on average are willing to pay at least 71.56 percent more than their current bill to eliminate the problem of electricity outages (Table 8, row 7). Moreover, the average WTP for the Turnbull upper bound estimate for a 50 percent reduction in outages is 32.37 percent of the current bill and the incremental WTP is 62.27 percent to eliminate all outages. The combined WTP to eliminate all electricity outages is 94.64 percent of the current electricity bill of such businesses (Table 6, row 9). The average WTP for the Kriström average for a 50 percent reduction in outages is 27.21 percent of the current bill, where the incremental WTP is a further 55.89 percent of the current bill to eliminate all outages. The combined WTP in order to eliminate all electricity outages is 83.1 percent of the current electricity bill of businesses. The Kriström mean estimates of the WTP by households and businesses are the midpoint values between the Turnbull upper and lower bound estimates for the WTP.

Parametric estimates are constructed by applying a binary logit model. This is carried out by econometrically estimating the WTP using logit regressions for a 50 percent and 100 percent decrease in outages based on respondents' answers to the bidding scheme employed in the interviews. Because of the missing values in responses to the survey for several of the potentially explanatory socio-economic variables of the WTP, the results of the logit regressions with continuous variables are not reported here.

In Table 4, household results are presented for the case when both initial and final bids are considered for the 50 percent reduction in outages and initial and final bids are considered for the 100 percent reduction in outages. The incremental WTP estimates are 39.91 percent and 54.58 percent of the current electricity bill respectively. With a WTP for a complete elimination of outages of 94.49 percent of the current electricity bill. (Table 6, row 5)

Table 4. Estimated Results of WTP Regressions (Households)

	Coefficient	Std. Err.	z	P>|z|
WTP for 50% decrease in outage based on the initial Bid and final Bid .				
WTP	39.91221	1.101113	36.25	0.000***
Log likelihood	-2800.362			
Number of obs.	1800			
WTP for 100% decrease in outage based on initial Bid and final Bid				
WTP	54.57752	1.076627	50.69	0.000***
Log likelihood	2870.6671			
Number of obs.	1800			

***significant at 1%, **significant at 5%

The information collected through the survey is also used to make parametric estimates of the WTP for reduced outages by business establishments. In Table 5, the results are presented for the case when both initial and final bids are considered for the 50 percent and 100 percent reduction in outages. The incremental WTP estimates are 37.31 percent and 88.81 percent, for the incremental 50 percent and 100 percent reduction of outages respectively. The WTP for a complete elimination of outages is estimated to be 125.72 percent of the current electricity bill (Table 6, row 10).

Table 5. Estimated results of WTP Regressions (Businesses)

	Coefficient	Std. Err.	z	P>|z|
WTP for 50% decrease in outage based on the initial Bid and final Bid				
WTP	37.30704	1.873024	19.92	0.000***
Log likelihood	-747.82137			
Number of obs.	590			
WTP for 100% decrease in outage based on the initial Bid and final Bid				
WTP	88.8064	4.740635	18.73	0.000***
Log likelihood	-1175.3683			
Number of obs.	590			

***significant at 1%, **significant at 5%

From the values reported in Table 6, a comparison can be made of the WTP estimates using the alternative estimation methods. For households and businesses, in all cases, the estimated WTP from the logit parametric estimate are larger than the upper bound Turnbull estimate. The logit estimate of the WTP by households for a 50 percent reduction in electricity outages is 39.91 percent of the bill while it is 36.26 percent for the upper Turnbull estimate. The incremental WTP to get to a 100 percent reduction in outages is 54.53 percent and 44.37 percent of the bill for the logit and the upper Turnbull estimate respectively. When considering the total amount that households are willing to pay to eliminate all electricity outage the logit estimate is 94.46 percent while the upper Turnbull estimate is 80.63 percent. However, in all cases the estimated WTP to move from a 50 percent correction of the outages to a 100 percent correction is significantly larger than the WTP for the 50 percent solution. The differences between the incremental WTP for a 50 percent reduction in outages and the incremental WTP for a 100 percent reduction in outages is an indication of how respondents value an increase in the improved reliability or quality of the service that comes with the complete elimination of outages. The percentage increase in the amount of electricity received for each of these improvements is theoretically the same, but a household values the second 50 percent increment from 5.6 to 14.6 percentage points of their current bill more highly. The "quality" of the additional improvement that eliminates the uncertainty about outages completely is something that people are willing to pay for.

Table 6. Non-Parametric and Parametric estimates of WTP for Reduced Electricity Outages

	Mean WTP (percentage of current monthly bill)		
	50% less outages	Incremental WTP 100% less outages	Total WTP for 100% less outages
Households (N=1800)			
1. Median	*26.30*	*31.30*	57.60
Non-Parametric Models			
2. Lower Bound (Turnbull)	29.22	34.84	64.06
3. Kriström	34.24	40.44	74.68
4. Upper Bound	39.26	44.37	83.63
Parametric Model			
5. Logit estimate	39.91	54.58	94.49
Businesses (N=590)			
6. Median	20.00	42.30	62.30
Non-Parametric Models			
7. Lower Bound (Turnbull)	22.05	49.51	71.56
8. Kriström	27.21	55.89	83.10
9. Upper Bound	32.37	62.27	94.64
Parametric Model			
10. Logit estimate	37.21	88.51	125.72

A comparison of the estimates of the WTP for business also shows that the logistic estimates are all larger than for any of the non-parametric estimates. At the same time, the difference between the WTP in a 50 percent reduction in outages and a 100 percent reduction is more striking and yet understandable. Businesses value the incremental improvement of reducing 50 percent of the outages at a WTP from 22.05 to 37.21 percent of their current bill. This is less than the WTP by households. Given that businesses have less flexibility in shifting their demand for electricity over the day and week, it is understandable that they place a lower value on a partial solution to their electricity problems. On the other hand, their valuation of the incremental improvement to a 100 percent elimination of outages is relatively much greater, ranging from 49.5 to 88.8 percent. In the case of businesses, the premium they are willing to pay over and above their WTP for a 50 percent improvement in service for an electricity service 100 percent free from the risk of outages is between 27 and 51 percent of their current bill. The WTP by business for a service that is totally reliable is about 1.3 times as great as the WTP by households. Given the high cost of uncertainty faced by businesses, they appear to be willing to pay more than households to be able to eliminate all the outages while being willing to pay less than households for a 50 percent reduction in outages.

Economic Benefits of an Improved Service

Estimates of the economic welfare benefits that would arise from investment and management practices to improve the poor electricity service can be derived using the estimates of the WTP presented in Tables 6 and 9 along with the revenue data by class of customer available from the reports of the electric utility (NEA, 2017) The WTP estimates are expressed as a percentage of the current electricity bill. By multiplying these estimates by the published values for the revenues collected by the NEA, one can obtain the WTP or gain in economic welfare, expressed in monetary units, from reducing the level of electricity outages in Nepal. These are estimates of the gross economic benefits. In order to determine the net economic benefits, the costs of additional investment and improved management required to bring about these improvements must be subtracted from the estimated gross benefits.

In 2017, the total sales revenue from the payment of electricity bills by non-business customers totalled Rs 22,339,620,000. This total was made up of the bills of domestic consumers of Rs 19,787,271,000 and for non-commercial consumers of Rs 2,552,349,000. The total sales revenue in 2017 for business electricity was Rs 21,708,067,000, which comprised of Rs 16,635,503,000 for industry consumers and Rs 5,072,564,000 for commercial consumers, (NEA, 2017). These values for the total amount of receipts from billings are combined with the three sets of WTP estimates for both households and businesses to construct a range of values, expressed in monetary terms, for the gross gain in economic welfare arising from reductions in electricity supply outages.

These estimates provide a low, medium and high estimate of the gross benefits arising from an initial 50 percent reduction in outages, a further 50 percent reduction in outages and the aggregated total reduction in electricity outages. The low estimates are calculated using the medium WTP by both households and businesses (Table 6, rows 1 and 6, respectively). The moderate estimate of the WTP by households and businesses is obtained by applying the average of the non-parametric estimates, which is also equal to the Kriström means (Table 6, rows 3 and 8). The higher estimate is obtained by the WTP estimates for the parametric estimates of this variable (Table 6, rows 5 and 10).

The annual estimates of the range of the monetary values of the gross benefits from improving the quality of the electricity service for both households and businesses in Nepal are reported in Table 7, section 5. In terms of annual gross benefits, the estimated value based on the median estimates of WTP for a 50 percent improvement ranges from US$ 96.4 million to a high estimate of US$ 125.8 million per year based on the parametric estimate of WTP. The value of the gross benefits using the Kriström mean value amounts to US$ 125.8 million. On the other hand, the estimated value placed on the next increment of improvement from 50 percent to 100 percent improvement ranges from US$ 152.6 million to US$ 296 million. For this level of improvement, the estimated annual value of the benefits amounts to US$ 204.3 million per year using the Kriström mean estimate of the WTP. Combining both these levels of improvements, the annual monetary values of benefits range from US$ 250 million derived from the median estimate of peoples' WTP to US$ 456.6 million with the estimate using the Kriström mean of the WTP giving us an annual value of US$ 324.4 million.

In order to address the problem associated with the quality of the electricity service in Nepal, a major set of investments will be needed to increase the capacity of both electricity generation and transmission. An example of one such investment is a major strengthening of the electricity transmission system in Nepal at a proposed cost of US$ 530 million. This investment is to be financed through a grant from the US government via the Compact between the Millennium Challenge Corporation and the Government of Nepal signed September 17, 2017. The counterpart organization within Nepal for the implementation of this project will be the National Electricity Authority, which contributed US$ 130 million of this total. It is thought that this project, in conjunction with other investments made in the generation sector, will greatly improve the availability and quality of the overall electricity service. (MCC, 2017). In addition, the National Electricity Authority (NEA, 2017) is in the process of undertaking a number of generation projects with a total cost of approximately US$ 350 million, facilitated by funding of US$ 150 million from the Asian Development Bank and several bilateral development assistance organizations. Hence, the total investment program of system improvement is approximately US$ 880 million.

Table 7. Estimate of the annual WTP for reduction in outages by consumer class for 2016/17

	Estimate of the Annual WTP in Rs		
	50% less outages	Incremental WTP 100% less outages	Total WTP for 100% less outages
1.Domestic & Non-Commercial Consumers			
Median	5,875,320,060	6,992,301,060	12,867,621,120
Kriström	7,425,689,688	9,559,123,398	16,334,730,144
Parametric	8,915,742,342	12,192,964,596	21,108,706,938
2.Industry & Commercial			
Median	4,341,613,400	9,182,512,341	13,524,125,741
Kriström	5,906,765,031	12,132,638,646	18,039,403,677
Parametric	8,077,571,731	19,213,810,102	27,291,381,832
3.Total Annual (Nepal Rs)			
Median	10,216,933,460	16,174,813,401	26,391,746,861
Kriström	13,332,454,719	21,691,762,044	34,374,133,821
Parametric	16,993,314,073	31,406,774,698	48,400,088,770
4.PV @10%, 20 years (Nepal Rs)			
Median	86,982,514,032	137,705,304,545	224,687,818,577
Kriström	113,506,702,788	184,674,198,358	292,646,378,597
Parametric	144,673,662,168	267,383,577,621	412,057,239,'789
5.Total Annual (US $)			
Median	96,386,165	152,592,579	248,978,744
Kriström	125,777,875	204,639,265	324,284,281
Parametric	160,'314,284	296,290,327	456,604,611
6.PV @10%, 20 years (US $)			
Median	820,589,755	1,299,106,647	2,119,696,402
Kriström	1,070,817,951	1,742,209,418	2,760,814,892
Parametric	1,364,845,870	2,522,486,581	3,887,332,451

Source: Electricity revenue by consumer class is published in NEA annual report, NEA, 2017

In a cost benefit analysis, we need to know the benefit and the costs associated with the investments required to address the problem of outages and voltage fluctuations of the current electricity service.

Most such investments in transmission and generation will have a life of at least 20 years. Hence, to construct a comparable estimate of the benefits of such an investment program a present value calculation is made of 20 years of the potential benefits of reduced outages using a real rate of discount of 10 percent.

The estimates of the range of the present value of the gross benefits from improving the quality of the electricity service for both households and businesses in Nepal are reported in Table 7, section 6. In terms of the present value of the benefits based on the median estimates of WTP for a 50 percent improvement, the value ranges from US$ 820.6 million, to a high estimate of the WTP of US$ 1,364.8 million. The present value of the benefits using the Kriström mean amounts to US$ 1,070.8 million. On the other hand, the estimated present value placed on the next increment of improvement from 50 percent to 100 percent ranges in present value from US$ 1,299.1 million to US$ 3,887.3 million. For this level of improvement, using the Kriström mean estimate of the WTP the estimated present value of the benefits amounts to US$ 1,747.2 per year. Combining both these levels of improvements, the present value of the benefits accruing over a period of 20 years ranges from US $ 2119.7 million to US$ 3,887.3 million. Using the Kriström mean for the WTP parameter yields a present value of US$ 2,760.8 million for the 20 year profile of benefits.

For illustrative purposes, a comparison is made of this set of present value of benefits with the previously discussed costs associated with NEA's proposed investment program of about US$ 880 million. This comparison indicates that the net present value of these investments for service improvement would be positive, even at the middle range estimate of the net present value of the benefit, if they were able to achieve only a 50 percent reduction in electricity outages. It is clear that if further investment were needed to effectively eliminate the level of electricity outages, it is highly likely to be justified if it is effective in further reducing the electricity outages.

5. Conclusion

The electricity utility currently operates with a poor record of revenue collection and suffers from very high losses in electricity transmission and distribution. The chronic deficits are reflected in the frequent outages and delays in investment necessary to strengthen the existing system. Customers of the public electricity utility are receiving an inefficient and costly service. The level of outages and voltage fluctuations are some of the greatest experienced by households and businesses anywhere in the world. This is the direct result of poor electricity system planning and governance. The recent damage experienced from severe earthquakes has further added to the decline in the electricity system's infrastructure and available service.

The estimates of the WTP for improved electricity service are large and provide clear evidence of the economic benefits to be derived from making electricity system investments that will reduce outages. Of course, the investments must be appropriate to effectively reduce the incidence of outages and voltage fluctuations. These estimates of willingness to pay provide the key parameter values for estimating the benefits of an effective rehabilitation and expansion investment program. Equal care must be taken in the design and implementation of an investment program. It should be the least-cost investment strategy to achieve these goals and also be organizationally sustainable so that a relapse into this situation does not occur in the future.

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