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Attribute Preferences and Economic Value of Green Electricity in Pakistan

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Attribute Preferences and Economic Value of Green Electricity in Pakistan

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Abstract: Huge reliance on thermal power for electricity generation, the power sector of Pakistan has become significant contributor to GHG emissions. Government has plans to improve and upgrade the electricity infrastructure through generating more electricity from renewable energy sources. In order to evaluate the economic benefits which people are expected to gain if different sources of green electricity are incre0ased in the system and their preferences for any specific renewable energy sources are aimed in this study. The objectives of this study were explored by employing choice experiment (CE). The respondents were divided into two broad categories of urban and rural. Three main sources of green electricity (Hydroelectricity, wind and solar) along with load shedding attribute were explored. The Conditional Logit Model and Mixed Logit Models were employed to identify the consumer's preferences and estimation of the marginal values. Results showed that the urban and rural consumers chose solar as the most preferred source and marginal values for this source is 0.17 cents per kWh consumption and 0.19 cents per kWh consumption in urban and rural models respectively.

1. Introduction

Electricity generated by fossil fuels refers to conventional energy means of non-renewable generation, having a bad impact on the environment and leads to climate change. However, world is facing worsening environmental change which requires a global attention to reduce carbon emissions [1]. In Pakistan, energy sector is one of the most prominent sectors in CO2 emission. If the attention will not be given to the transition of this sector, it can contribute more in increasing emission in future. The energy sector can be transformed through dependence on local renewable energy sources for electricity generation which are in abundance in the country. The ‘‘green’’ electricity is generated from renewable energy sources. These sources can be solar, wind, hydro, geothermal and biomass which have no or very less harmful impact on the environment [2].

Rapidly growing economies are seeking to secure stable energy supplies in a time when the environmental impacts of energy production are coming under growing scrutiny. More countries are focusing on developing technologies beyond traditional resource extraction. The development of these clean or renewable energy technologies can provide economic opportunities to countries with substantial traditional energy resources and countries that lack such resources by offering an alternative means to power their economies and generate jobs for their citizens. Renewable energy is rapidly growing sources now a days and several predictions have been made about the fast expansion of these resources in near future [3]. Renewables delivered nearly 20% of global electricity generated in 2010. Large hydropower made up more than 80% of global renewable power and 16% of global power generation overall [4]. The share of thermal power installed capacity in the country was 65.50% in 2015-16, and the electricity generated by the thermal power plants was 64.01% in 2014-15.

In Pakistan, the Government has plans to improve and upgrade the electricity infrastructure through generating more electricity from renewable energy sources. In order to evaluate the economic benefits which people are expected to gain if the green electricity sources are increased in the system, their preferences for any specific renewable energy sources will considered in this study. There are no existing estimates of willingness to pay (WTP) for better service of electricity found in Pakistan. A small number of such studies have been found elsewhere in the world but according to our knowledge there are no valuation studies found in energy sector in Pakistan.

Green energy has several sources like Wind (air), Hydro (water) and Solar (sun). Hence, it is important to know which sources of green electricity is preferred by Pakistani people and how much are they willing to pay extra for that source of green electricity. Different previous studies on renewable energy listed potential attributes of renewable energy which are preferred by people in different settings. Some of the attributes included (% of electricity from solar, % of electricity from wind, mixtures of renewable energy sources, location of renewable energy projects, size of power plants, local biodiversity, land scape and many more). Each attribute comes with different levels and with several benefits. They have found different preferences of people in order to increase the share of electricity from renewable energy sources. Some preferred solar, some preferred wind, some preferred mix of sources and some are more willing to pay for jobs, land scape and preserving local biodiversity. However, these issues are still uncertain and this study tried to add knowledge in attempt to address these issues.

2. Methodology

2.1 Choice Experiment

The choice modelling approach is another sub approach of stated preference method. Choice modelling also called sometimes 'Conjoint Analysis' and it can be divided into four subcategories. (a) Choice experiments (CE); (b) pair comparisons; (c) contingent ranking; (d) contingent rating. However, this study is using a choice experiment where respondents are given a set of attributes to choose the best among them. There are two features of CE that are related to the theory of value by [5] and random utility theory by [6].

2.1.1 Conditional Logit Model

This section will show how to estimate the individual level. Contingent experiments basically allow respondents to act as decision-makers and choose from among the attributes or policy options given. The CE is the same as the contingent valuation method in the random utility model. The random utility model can be a good estimator of the unknown utility function. This theory will directly lead to the probability of when choosing the alternative from a different set of the attribute given [7 – 8].

The estimation for the conditional logit model can be accomplished using the software packages, such as LIMDEP, STATA, SPSS and N-Gene software. The most important significance of the logit model is the selections from the choice set must obey the independence from irrelevant alternatives (IIA) axiom. Based on [9] IIA axiom is a ratio of probabilities of choosing one alternative over another is unaffected by another set of alternatives.

2.1.2 The random parameter (or mixed) logit model

[10] indicate that, the Mixed Logit (ML) model or also being called as a random parameter logit (RPL). ML and RPL only differ in terms of interpretation, but being derived with the same approach [11]. The words 'mixed logit' is used in to reflect that the model is contained with a mixture of logit models. The use of ML can be related in describing the various error specification in a discrete choice model (i.e. error components, random effects, unobserved heterogeneity).

2.2 Selection of attributes and level

The attribute selection and defining its level is the first step in developing choice modelling. The attributes can be selected through literature review and expert opinion. The level can also be defined by directly asking the management or can be defined by current issues in the relevant field. According to [12 – 13], attributes should be demand relevant, policy-relevant and measurable. Considering this criterion is very important in the selection of attributes. The attributes chosen to use in this study are obtained from literature review [14 – 19]. The selected attributes are:

1. Sources of renewable electricity
   a. % of electricity from hydro
   b. % of electricity from solar
   c. % of electricity from wind
   d. Load shedding in hours
2. Price (monthly surcharge on electricity bill)

After finalizing the attributes selection then follow the selection of their appropriate levels. All the attributes are presented with their appropriate levels after consultation with experts and focus group discussion. Further details regarding attributes and their respective levels are given in Table 1.

Table 1. Attributes and level

Attributes	Description	Levels	Status quo	Source
% of electricity from hydro	It is a quantity of electricity usage generated by hydro energy sources.	35%, 40% and 45%	30%	Pakistan Economic survey (2017) Nepra (2016)
% of electricity from solar	It is a quantity of electricity usage generated by Solar energy.	3% and 5%	Less than 1 %	Gracia, Barreiro-Hurlé, & Pérez y Pérez (2012)
% of electricity from wind	It is a quantity of electricity usage generated by wind energy.	3% and 5%	Less than 1 %	Gracia, Barreiro-Hurlé, & Pérez y Pérez (2012)
Load Shedding	Hours of blackout (Powercut) per day	5-6 hours and No load shedding at all	10 hours average	(17)
Price	It is the amount you need to pay to use electricity from renewable energy sources	0.20, 0.30, 0.40 and 0.50	0.10 cent/kWh	Gracia, Barreiro-Hurle, & Perez y Perez (2012) Nepra (2016)

3. Results and Discussion

3.1 Respondent's Profile

The respondents are categorized into two categories, i.e. Rural and Urban. Both the respondents' categories were interviewed through questionnaires. All the respondents were electricity consumers of Lahore electric supply company.

3.2 Choice Experiment (CM) Analysis

This section provides information about the choice experiment study that people preferred which attribute more. The econometric software N-logit version 4.0 has been utilized for the analysis purpose.

3.2.1 Descriptive statistics

The descriptive statistics has given in Table 2. The mean, standard deviation, minimum and maximum levels are given in the following Table below. The value 1 represents the status quo option and value in the maximum column is the highest level. For instance, in the first attribute “hydro”, the status quo is 1, which means 30% and 4 refers to 45%, which is the highest level offered to respondents.

Table 2. Descriptive statistics of attributes in choice experiments.

		Urban				Rural			
Attribute	**Description**	**Mean**	**S.D**	**Min**	**Max**	**Mean**	**S.D**	**Min**	**Max**
HY	Hydro	1.82	1.09	1	4	1.82	1.08	1	4
WND	Wind	1.61	0.74	1	3	1.61	0.74	1	3
SOL	Solar	1.61	0.74	1	3	1.61	0.74	1	3
LS	Load Shedding	1.58	0.74	1	3	1.58	0.74	1	3
Price	Voluntary Price	0.23	0.14	0.1	0.5	0.23	0.14	0.1	0.5

3.2.2 Conditional Logit Model

This section explains the conditional logit model including specification of the level of attributes for the green electricity improvement in Pakistan. Model specification is stated as below in equation 1.

$$U = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \epsilon \quad \text{Eq. 1}$$

Where:
U = Utility
$\beta_1 X_1$ = 35% of electricity generation from Hydro (HY2)
$\beta_2 X_2$ = 40% of electricity generation from Hydro (HY3)
$\beta_3 X_3$ = 45% of electricity generation from Hydro (HY4)
$\beta_4 X_4$ = 3% of electricity generation from Wind (WND2)
$\beta_5 X_5$ = 5% of electricity generation from Wind (WND3)
$\beta_6 X_6$ = 3% of electricity generation from Solar (SOL2)
$\beta_7 X_7$ = 5% of electricity generation from Solar (SOL3)
$\beta_8 X_8$ = 5-6 hours of load shedding (LS2)
$\beta_9 X_9$ = No load shedding at all (LS3)
$\beta_{10} X_{10}$ = Voluntary Price (PRICE)

3.2.3 Simple conditional and interaction logit models

Simple conditional logit model presents the information regarding respondents’ choice towards the attributes used in this study. The simple conditional logit model is specified to account for the respondent’s choice between the options presented to them.

The respondent’s socioeconomic data can be employed into the conditional logit model as interaction with the main attribute. These interactions help to provide substantial data set about the particular influences of choice on each attribute level used in this study.

In the CL interactions model for the urban and rural samples, there are 45 interaction variables incorporated, but only significant variables are presented, except for the main attributes. The analysis of the model begins with the inclusion of all of the interaction variables then drops the insignificant variables. This step continues until all the interaction variables are significant. The final economic function of the urban and rural models is given in equation 2 and 3 respectively:

$$\boldsymbol{U_{urban}} = \beta_1 X_{HY2} + \beta_2 X_{HY3} + \beta_3 X_{HY4} + \beta_4 X_{WND2} + \beta_5 X_{WND3} + \beta_6 X_{SOL2} + \beta_7 X_{SOL3} + \beta_8 X_{LS2} + \beta_9 X_{LS3} + \beta_{10} X_{PRICE} + \beta_{11} X_{HY4} S_{AGE} + \beta_{12} X_{WND2} S_{AGE} + \beta_{13} X_{WND3} S_{AGE} + \beta_{14} X_{SOL2} S_{AGE} + \beta_{15} X_{SOL3} S_{AGE} +$$

$$\beta_{16}X_{LS2}S_{AGE} + \beta_{17}X_{HY3}S_{INC} + \beta_{18}X_{HY4}S_{INC} + \beta_{19}X_{WND2}S_{INC} + \beta_{20}X_{WND3}S_{INC} + \beta_{21}X_{SOL2}S_{INC} + \beta_{22}X_{SOL3}S_{INC} + \beta_{23}X_{LS2}S_{INC} + \beta_{24}X_{LS3}S_{INC} + \beta_{25}X_{WND2}S_{GEN} + \epsilon \quad \text{Eq. 2}$$

$$\boldsymbol{U_{rural}} = \beta_1 X_{HY2} + \beta_2 X_{HY3} + \beta_3 X_{HY4} + \beta_4 X_{WND2} + \beta_5 X_{WND3} + \beta_6 X_{SOL2} + \beta_7 X_{SOL3} + \beta_8 X_{LS2} + \beta_9 X_{LS3} + \beta_{10}X_{PRICE} + \beta_{11}X_{HY4}S_{AGE} + \beta_{12}X_{SOL2}S_{AGE} + \beta_{13}X_{HY3}S_{EDU} + \beta_{14}X_{HY4}S_{EDU} + \beta_{15}X_{SOL2}S_{EDU} + \beta_{16}X_{SOL3}S_{EDU} + \beta_{17}X_{LS2}S_{EDU} + \beta_{18}X_{LS3}S_{EDU} + \beta_{19}X_{HY3}S_{INC} + \beta_{20}X_{HY4}S_{INC} + \beta_{21}X_{SOL3}S_{INC} + \beta_{22}X_{LS2}S_{INC} + \beta_{23}X_{LS3}S_{GEN} + \beta_{24}X_{SOL2}S_{WOK} + \beta_{25}X_{LS3}S_{WOK} + \epsilon \quad \text{Eq. 3}$$

This study included five demographic variables in the model, namely; age (AGE), education (EDU), income (INC), gender (GEN) and work (WOK). These variables affected the model positively and increase model fit. When we compared both the interaction models with the simple logit model, we have found that the Pseudo-R^2 has been improved in both urban and rural models.

3.2.4 Basic mixed logit model

The mixed logit model is a highly flexible discrete choice model that relaxes many of the assumptions of the CL and MNL model. For example, the ML model relaxes the assumption of homogeneous preferences across respondents for all non-price attributes.

In this study, there are two stages of the ML model estimation. Firstly, the simple ML models for both urban and rural samples were estimated and analyzed. Then, the existence of taste heterogeneity around the population means parameter was determined by looking at the significant standard deviation coefficients from the mean parameter.

Secondly, the estimation of the ML model also allowed the primary attributes and interaction attributes to enter the indirect utility specification. Estimates were derived for both urban and rural samples of respondents. These interactions models reveal the influence of the characteristics of respondents in the preference distribution. The results derived from the simple and interaction ML models for both of the samples are then compared with the results of the simple and interaction CL models in the previous section, using the likelihood ratio test.

3.2.5 Simple mixed logit model

All attribute levels of simple mixed logit models are significant at 1% level with a correct expected sign in both urban and rural model. The values of AIC are also decreased from basic ML model to simple ML model for both urban and rural samples. In the CL interactions model for the urban and rural samples, there are 45 interaction variables incorporated, but only significant variables are presented, except for the main attributes. The analysis of the model begins with the inclusion of all of the interaction variables then drops the insignificant variables. This step continues until all the interaction variables are significant.

3.2.6 WTP Estimate

Willingness to pay can be interpreted as the maximum amount an individual is willing to pay to secure the benefit or worth of having goods or to avoid unwanted goods. The WTP for each attribute is calculated as the ratio of the attribute coefficients with the price coefficient using the Wald procedure (Delta method) in Limdep 8.0. Table 3 presents the WTP values (in cents per unit of electricity consumed) for the main attribute in the urban and rural samples for the simple CL model and the CL interactions model respectively.

Table 3. Marginal WTP Estimates (in Cents) from Simple CL and Interaction Model (Urban and Rural)

	Urban		**Rural**	
Variable	**CL Simple**	**CL Interaction**	**CL Simple**	**CL Interaction**
HY2	0.032(*)	0.040(***)	0.054(***)	0.058(***)
HY3	0.180(***)	-0.033	0.246(***)	0.096(***)
HY4	0.200(***)	0.091(***)	0.205(***)	0.050
WND2	0.169(***)	0.150(***)	0.167(***)	0.162(***)

WND3	0.079(***)	0.054(*)	0.144(***)	0.148(***)
SOL2	0.220(***)	0.138(***)	0.282(***)	0.228(***)
SOL3	0.276(***)	0.137(***)	0.367(***)	0.066(*)
LS2	0.193(***)	0.108(***)	0.184(***)	0.044(*)
LS3	0.112(***)	0.073(***)	0.150(***)	0.217(***)

Note: *Significant at 10%; **Significant at 5%; ***Significant at 1%. However, only the significance level is given in brackets.

According to the marginal values of CL urban simple model, all are positive and significant at 1% level except HY2, which is significant at only 10% level. In HY attribute, HY4 is the highest level for hydroelectricity with the highest willingness to pay value i.e. 0.20 cents per unit of electricity consumption. The significance levels (t-stat) are given in brackets with all the marginal values so that we can focus on significant variables only. Willingness to pay for HY3 and HY2 is 18 cents and 0.032 cents respectively. HY attributes' marginal values for CL rural simple model are 0.054, 0.246 and 0.205 for HY2, HY3 and HY4 respectively, which shows that the rural respondents are willing to pay more for HY3 attribute instead of the highest level of HY attribute. The marginal values for the levels of WND attribute in the urban model are 0.169 and 0.079 cents for WND2 and WND3 respectively. Whereas, marginal values for the levels of WND attribute in the rural model are 0.167 and 0.144 cents for WND2 and WND3 respectively. This shows that respondents are more willing to pay for all levels of wind energy than their urban counterpart. The values for SOL attribute are, SOL2 (0.220 cents) and SOL3 (0.276 cents) for urban simple CL model and SOL2 (0.282 cents) and SOL3 (0.367 cents) for rural. Both the respondents from urban and rural are willing to pay a high amount for SOL attribute, which shows that the respondents want to increase the share of solar energy very much because most of the consumers have awareness and knowledge about the utilization of solar energy. Especially the rural respondents willing to pay more than the urban respondents for the highest level of solar energy. The marginal values for the levels of LS attribute in the urban model are 0.193 and 0.112 cents for LS2 and LS3 respectively. Whereas, marginal values for the levels of LS attribute in the rural model are 0.184 and 0.150 cents for LS2 and LS3 respectively. It is very interesting that the respondents from rural areas are willing to pay more for the highest level of load shedding attribute but if when we looked deeply into this then we have found the reason that the respondents from the rural areas are more affected by the load shedding then the urban areas. Therefore, rural respondents are willing to pay more to reduce blackouts.

On the other hand, the marginal values of interaction CL models have been decreased in most of the cases for both urban and rural models. In urban CL interaction model, HY2, HY4 is 0.040 and 0.091 cents respectively, whereas HY3 shows negative willingness to pay but insignificant. Attribute HY in rural CL interaction model shows marginal values for HY2 is 0.058, for HY3 is 0.096 and for HY4 is 0.050 but insignificant, whereas there is no negative marginal value in rural CL interaction model. For WND attribute, marginal values again decreased in CL interaction urban model with 0.150 for WND2 and 0.054 for WND3. While, marginal value for WND2 in CL interaction rural model has slightly decreased which is 0.162, but the marginal value for WND3 has been increased which is 0.148 cents. This shows that wind energy is highly preferred for rural respondents on both levels. The marginal values for solar energy (SOL) have been decreased for all the level in both the models (urban and rural). In urban CL interaction model, SOL2 is 0.138 and SOL3 is 0.137, while in rural CL interaction model, these values are 0.228 and 0.066 respectively. The marginal values for Load shedding (LS) have been decreased in CL urban interaction model, which are 0.108 and 0.073 for LS2 and LS3 respectively. The marginal value for the rural model for LS2 is 0.044, whereas the marginal value for the highest level of the attribute (LS3) has been increased drastically, which is 0.217 cents per unit of electricity consumption. This clearly states that load shedding is very important attribute for the rural respondents. Table 4 presents the WTP values for the primary attributes in the urban and rural samples for the simple ML model and ML interactions model respectively.

Table 4. Marginal WTP Estimates (in Cents) from Simple ML and Interaction ML Model (Urban and Rural)

	Urban		**Rural**	
Variable	**ML Simple**	**ML Interaction**	**ML Simple**	**ML Interaction**
HY2	0.0004(***)	0.022(*)	0.049(***)	0.051(***)
HY3	0.154(***)	-0.022	0.243(***)	0.093(***)
HY4	0.149(***)	0.094(**)	0.201(***)	0.042
WND2	0.182(***)	0.153(***)	0.167(***)	0.163(***)
WND3	0.093(***)	0.045(*)	0.142(***)	0.146(***)
SOL2	0.211(***)	0.138(***)	0.279(***)	0.192(***)
SOL3	0.276(***)	0.172(***)	0.367(***)	0.079(**)
LS2	0.202(***)	0.124(***)	0.183(***)	0.046(**)
LS3	0.093(***)	0.055(***)	0.148(***)	0.161(***)

Note: *Significant at 10%; **Significant at 5%; ***Significant at 1%. However, only the significance level has given in brackets.

In the simple ML – urban model (Table 4), the results demonstrate that the respondents express their highest WTP value of 0.276 cents for the SOL3, followed by 0.211 for SOL2. In simple ML – rural model, the respondents also express their highest willingness to pay the value of SOL2 and SOL3, which are 0.279 and 0.367. These results revealed that the respondents in both samples had the same magnitude for WTP ranking estimates for solar energy, which is similar to that reported in simple Conditional Logit model. Moreover, marginal values of WND2 and WND3 for urban simple ML model are 0.182 and 0.093 respectively. However, values for WND2 and WND3 for rural simple ML model are 0.167 and 0.142, which shows that rural respondents are more willing to pay for WND3 then the urban respondents. WTP for HY2, HY3, and HY4 for urban are 0.0004, 0.154, and 0.149, and for rural are 0.049, 0.243, and 0.201. Moreover, for LS attribute; urban respondents' WTP is 0.202 and 0.093 for LS2 and LS3 respectively, whereas rural WTP is 0.183 and 0.148. These results revealed that the rural respondents are more willing to pay for load shedding attribute in order to avoid complete blackouts.

According to Table 4, the respondent from urban sample had the highest marginal value of 0.172 cents per unit of electricity consumed for the provision of the highest level of solar (SOL3), followed by 0.153 for a medium level of wind (WND2), followed by 0.138 for SOL2 and 0.124 for LS2. On the other hand, the respondent from rural sample had the highest marginal value of 0.192 cents per unit of electricity consumed for the provision of medium level of solar energy (SOL2), followed by 0.163 for a medium level of wind (WND2). Followed by 0.161 for the highest level (LS3) of load shedding (means; no load shedding at all) and 0.146 cents per unit for the highest level of wind energy (WND3). Hydroelectricity was the least preferred for both urban and rural models. HY3 has negative WTP, and become insignificant in ML urban interaction model. Whereas, HY4 become insignificant with a positive sign in the rural ML model.

4. Conclusion and policy recommendation

We have used a conditional logit model and a mixed logit model in order to estimate the preference of the respondents regarding renewable energy in Pakistan. Our results found that the mixed logit model is best in terms of statistical parameters of model fit. In our final mixed logit model, we have found that people preferred solar energy most. However, we have found the difference in preference in other attributes between urban and rural respondents. Rural respondents preferred load-shedding attribute more than the urban respondents because the rural areas are more affected by the electricity supply and demand gap. Moreover, the demographics of the respondents also played a vital role in determining the preferences of the attributes.

The results of this study provide several policy recommendations for the policy-makers in the country. The key results proposed that both urban and rural respondents preferred solar energy most. In this regard, policy makers should focus on solar energy and formulate policies to enhance investment especially on solar source of electricity. The government should give more incentives to the domestic, industrial and large-scale commercial consumers of electricity who develop their own solar electricity systems to generate electricity by their own. These consumers should be promoted by giving interest-free loans, tax redemptions and reduced tariff. By this way, the other people will also be motivated to increase their own share of electricity on a small scale, which will ultimately reduce the burden on the national grid. Keeping in view the of ever-increasing demand for electricity, the government should focus more on long term planning for renewable sources of electricity. Moreover, the respondents also preferred wind sources of green electricity and load shedding attributes, which means that if the load shedding of electricity will be reduced the people will more willing to pay for green electricity.

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