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Determinants of Residential Electricity Demand: Empirical Evidence from Pakistan

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Abstract

This study is based on the estimation of residential demand of electricity for Pakistan with major focus on the income elasticities and the luxury appliances impact over the demand. The monthly electricity unit consumption is used as dependent variable that is constructed through backward induction method from monthly electricity expenditure that help to find clear dimensions of the demand. For estimation of demand Two Stage Least Square method of estimation has used with the five explanatory variables; household monthly income, household size, dwelling size, appliances and luxury appliances. The empirical analysis is conducted by using Two Stage Least Square methods. The empirical findings represent the positive significant income elasticities that are almost the same across the different income groups in various regions. The household demand for electricity has strong response to the luxury appliances. The household size revealed negative significant response to the residential demand for electricity. The dwelling size and appliances have shown positive significant or insignificant impact over the residential electricity demand.

Keywords: Residential Demand, Backward Induction Method, Income Elasticities, Pakistan.

Introduction

There are two notable features of demand for electricity especially in developing countries. Firstly, an exponential increase in demand for electricity; forecast estimate shows that the global demand for energy rises by 25 percent by 2040 which comes from developing countries and demand could have more than doubled without efficiency gains (EMC, 2016). Structural transition including migration from rural to city settings and shift from under developed to developing or developed stage and change in growth paradigm; such as increase in per capita consumption of modern energy, population growth and demonstration effect are held responsible for exponential growth of demand for electricity. Secondly, huge demand supply gap emerges in developing countries causing economic losses both at micro and macro levels.

After the paradigm shift of Pakistan government into new phase of democracy by the end of Musharraf regime 2008, load shedding problem was started and due to aforesaid factors of energy demand, exponential increase became sever energy crisis. On average, shortage of 7000 MW badly hit the all sectors of the economy including manufacturing, services and residential sectors (Javid & Qayyum, 2014; Nawaz, Iqbal, & Anwar, 2013; Nawaz et al., 2014; Rashid & Sahir, 2015). This crisis effect household sector more severally as compare to manufacturing and services sectors. Firstly, residential demand for electricity has increased with faster rate, as compared to other sector over the last two decades; due to structural transitions, growth in the use electrical appliances and modernization. Secondly, electricity demand-supply gap has severely affected the residential sector due to lack of alternatives to produce cheap electricity. Existing studies based on Pakistan has analyzed overall or sector-wise electricity demand, but only from macroeconomic perspective using time series data with primary focus on price and income elasticities using VAR and ARDL procedures (Nasir et.al 2008; Syed, S. H. 2011; Nawas et. al 2013; Javid & Qayyum, 2014). Disaggregate analysis has done on household sector using survey data but these studies are limited with cities or province only (Khan et.al 2008; Chaudhry, A. A. 2010; Jamil et.al 2011). Past studies tend to exclude the basic household characteristics of overall electricity consumers around the different areas of Pakistan that are covered in Household Income and Expenditure Survey Pakistan. Various studies, based on residential sector at country, province or district levels using cross section and panel data, has used consumption as proxy of electricity demand that cannot properly reveal demand (Fell, Li, & Paul, 2014; Filippini & Pachauri, 2004; Jacobsen, Kotchen, & Vandenbergh, 2012; Zhou & Teng, 2013; Darwish et al, 2018). Javid and Qayyum (2014) investigate the relationship between electricity consumption, real economic activity and prices using underlying energy demand trend (UEDT) for the residential sector using time series data over the period 1972-2012. This study finds that there is a weak relation between electricity consumption and prices in Pakistan.

Given this background, it is essential to investigate the residential demand for electricity and its determinants in at household level to find the factors responsible for exponential growth of demand for electricity in residential sector. Past empirical studies on residential demand for electricity can be extended in three dimensions. Firstly, micro approach is used for modeling residential electricity demand which help to deal with the different household groups by incorporating the basic characteristics of households. It will provide better picture to government to design policy framework to overcome both issue i.e. to manage demand and introduce efficiency in electricity sectors. Secondly, the available literature used total energy consumption as a proxy of electricity demand by the residential sector at macro level; however, it provides limited picture of actual use of electricity by the household. This study extends the practice of past studies by constructing actual use of electricity units from the electricity expenditure using backward induction method (BIM). It is noticeable that electricity bill is charged at different rate against different slabs of electricity used; hence, BIM helps to produce actual electricity unit consumed by the households considering different slabs. Electricity tariff rates in Pakistan consist of different slabs like, the tariff rate for units 0-50 is 1.87, 50-100 rate is 4.45, from 101-300 rate is 6.73, 301-700 rate is 10.65 and for all units above 700 the rate is 13.29[1]. Finally, there is a need to provide comparative analysis between luxury and necessary appliances across different set of households for electricity demand as past studies tend to ignore this aspect. This study aims to answer whether price escalation strategy help to tackle exponential demand of electricity and in which segments of the economy.

[1] These rates are taken from the electricity bill for the month of March 2011

The main objective of this study is to investigate the determinants of residential electricity demand in Pakistan using Household Income and Expenditure Survey data. Specific aims of this study are; to estimate the determinants of residential electricity demand at national, sub-national, regional and income group levels as well as; to investigate the impact of luxury appliances and necessary appliances on the residential demand for electricity. For modeling residential demand for electricity in Pakistan, this study adopts the micro foundation provided by Filippini and Pachauri (2004). The household utility function is used to derive residential electricity demand by utilizing Household Integrated and Economic Survey (HIES) 2010-11- a nationally representative household data. The model has been estimated using Two Stage Least Square (TSLS) technique which tackles the endogeneity among the variables. Existing literature revealed problem of endogeneity in income that is covered by using instrumental variable through TSLS. Food expenditure is used as instrumental variable because it is relevant with income but doesn't link with energy demand (Dilaver & Hunt, 2011; Reiss & White, 2005).

The rest of paper is structured as follow: next section provides a review of past studies follows by the modeling framework, data and estimation methodology. The subsequent section elaborates the empirical results and last section concludes the discussion of the results.

Literature Review

Demand for electricity consumption is not direct rather it is derived demand as it is consumed indirectly though utility yielding goods (Deaton, 1980). Residential demand for electricity is the currently burning issues in the world especially in developing countries. Due to rapid modernization, urbanization and limited supply improvement in the electricity, the rapid growing residential electricity demand became the crucial problem of the economies. It is influenced by the various factors like electricity prices, income, weather conditions, electric appliances etc household (Filippini & Pachauri, 2004; Jacobsen et al., 2012; Naeem Ur Rehman, Tariq, & Khan, 2010).

The channel through which these variables affect residential electricity demand is; electricity prices are inversely related to demand, in different weather conditions individual needs those appliances for their comfort, with increase in household income the demand for goods increase as well, the household size and dwelling size normally have positive related to demand (Eskeland & Mideksa, 2009; Filippini & Pachauri, 2004; Shi, Zheng, & Song, 2012). Energy consumptions is linked with in-efficiency and structural changes in commercial sector while rapid population growth and modernization in residential sector (Reddy, 1998). Price and income are frequently used variables the estimation of elasticity (Adelekan & Jerome, 2006; Alberini, Gans, & Velez-Lopez, 2011; Filippini & Pachauri, 2004; Ito, 2012; Khan & Ahmad, 2008; Reiss & White, 2005). Price and income are not only the determinants of the residential electricity demand, the electric appliances have also positive significance over the demand function (Fell et al., 2014; Filippini & Pachauri, 2004; Naeem Ur Rehman et al., 2010; Shi et al., 2012). Then the demographic and geographic variable have also significant impact over the electricity demand for that purpose the lifestyle (household size, dwelling size, number of rooms etc.) variable is been used (Fell et al., 2014; Shi et al., 2012). For the determination of the electricity demand function the utility maximization approach is used as well (Filippini & Pachauri, 2004). European study explained the weather condition have significant impact on the electricity consumption. On average climate change reduce the demand for electricity in the European countries (Eskeland & Mideksa, 2009). Income, taste, weather condition and time have significant impact over the residential electricity demand function (Clarkson, 1962; Deaton, 1980). Then the household electricity demand is determined by the economic and non-economic factors using utility maximization approach on survey data (Fell et al., 2014; Naeem Ur Rehman et al., 2010; Paul, Myers, & Palmer, 2009).

In the recent studies, the future electricity demand has been estimated frequently that shows the flexibility in the demand through influential factors (D'hulst et al., 2015; Eryilmaz & Sergici, 2016). On the basis of short run analysis, with the help of social and climate variable, one month ahead residential electricity demand forecast has made in South Korea (Son & Kim, 2016). A gravity-based residential electricity demand analysis, used for the long run estimation after 34 year in Japan (Yamagata, Murakami, & Seya, 2015). Energy consumptions is linked with in-efficiency and structural changes in commercial sector while rapid population growth and modernization in residential sector (Reddy, 1998). Price and income are frequently used variables the estimation of elasticity (Adelekan & Jerome, 2006; Alberini et al., 2011; Filippini & Pachauri, 2004; Ito, 2012; Khan & Ahmad, 2008; Reiss & White, 2005).

In Pakistan case, electricity demand is estimated for future using Smooth Transition Auto-Regression (STAR) Model for 41 years period. For development, electricity demand is consider as major factor (Nawaz et al., 2014). Unexpected fluctuations in electricity consumption and technical efficiency create positive relationship whereas electricity prices have negative relationship with sectorial demand for electricity in long run. Price policies have adverse while efficiency improvement policies have positive significant effect on electricity output (Alter & Syed, 2011; Burney & Akhtar, 1990; Eiswerth, Abendroth, Ciliano, Ouerghi, & Ozog, 1998). On the basis of Holt-Winter which is most appropriate method for estimation in Pakistan and ARIMA model, electricity consumption is forecast at component wise as well as overall level. There is stable mechanism for long run price and income relationship has investigated with macroeconomic (Jamil & Ahmad, 2010, 2011; Shahbaz & Feridun, 2012). For long run electricity demand, FDI, income and population growth are major determinants with positive elasticities by 0.056%, 0.973% and 1.605% respectively. Dynamic short run, unidirectional causality is investigated between population growth and electricity consumption (Zaman, Khan, Ahmad, & Rustam, 2012).

Normally electricity prices have significantly negative whereas household income has positive impact over the residential demand for electricity, but in the recent studies the demand for electricity is considered as necessity good, where prices have insignificant and household income has very minor impact on residential demand for electricity. Price and income are not only the determinants of the residential electricity demand, the electric appliances have also positive significance over the demand function (Fell et al., 2014; Filippini & Pachauri, 2004; Naeem Ur Rehman et al., 2010; Shi et al., 2012). Among the electric appliances, the luxury appliances e.g. air-conditioner, refrigerator, etc. have strong and positive significant impact over the demand. The geographic variables have also significant impact over the electricity demand for that purpose the lifestyle (household size, dwelling size, number of rooms etc.) variable is been used (Fell et al., 2014; Shi et al., 2012). Because electricity consumption is positively correlated with the size of the house, greater the house size greater will be the demand for electricity. Normally, household size and number of rooms have positive significant impact over the demand for electricity. For the determination of the electricity demand function the utility maximization approach is used as well (Filippini & Pachauri, 2004). Weather conditions considered as major influential determinant of electricity demand. The demand will be increased in the extreme weather summer and winter season, where as in the moderate weather the demand for electricity remains moderately effected by the weather conditions. European study explained the weather condition have significant impact on the electricity consumption. On average climate change reduce the demand for electricity in the European countries (Eskeland & Mideksa, 2009). Income, taste, weather condition and time have significant impact over the residential electricity demand function (Clarkson, 1962; Deaton, 1980). The household electricity demand is determined by the economic and non-economic factors using utility maximization approach on survey data. For budget constraint function, simple linear budget, nonlinear budget and kinked budget constraint is being used (Fell et al., 2014; Naeem Ur Rehman et al., 2010; Paul et al., 2009).

For the estimations of long run causal relationships among the residential demand for electricity and other macroeconomic variables granger causality with vector auto regressive model (VAR), error correction model, auto regressive distributed lags, and simple and panel co-integration test were used by researchers (Nasir et al., 2008; Javid & Qayyum, 2014; Dilaver & Hunt, 2011; Reiss & White, 2005; (Hung & Huang, 2015; Jebran, 2013; Pourazarm & Cooray, 2013). While for short run elasticities estimation OLS, GLS and GMM method are used frequently. While for the area based control demand analysis cohort-component method for population projection and simple population projection methods are used in the literature ((Fell et al., 2014; Filippini & Pachauri, 2004; Khattak et al., 2010).

Electricity crisis at residential sector can only be resolved by designing appropriate policies specifically for this sector that has remained missing in previous energy policies. The government ad hoc measures, non-transparent and unaccountable system and the stakeholder undue involvement while designing policies became as cause of inconsistent, inefficient and non-comprehensive policies. In Power Policy 1994, huge incentive provision to IPPs led energy surplus through only supply sector at the cost of high electricity tariff but this policy was general without incorporation of residential sector. Power Policy 2002 was completely designed to control electricity high tariff that was failure of first policy again there were no focus to residential sector. In 2006 Renewable energy policy was designed in Musharaf regime that was failed due to lack of new political intentions. Power Policy 2013 is a comprehensive work done by policy makers that incorporating all aspects but only on supply side. There is need to work on the demand side as well like National Energy Conservation Center (ENERCON) is contributing on demand side but still there is a room for improvement.

Data and Methodology

Modeling Framework

The study proceeds from the optimal behavior of the household. There are two functions, production technology and the utility function of a household. The technology function is vital because household gets some goods from a market that cannot be consumed directly so by combining different inputs he produces new good that can be consumed. So the commodity X is composite goods that uses electricity and any capital stock for the production and give utility to the consumer at household level. This technology function depends upon two inputs, E (electricity) and S (capital stock use for production of X). Whereas utility function depends on two commodities X and Z whereas commodity X is composite good and commodity Z consist of all those goods which provides direct utility to consumer whereas D and G are demographic and Geographic variables that effect the consumer preferences;

Equation (1) is technology function of good X that depends upon electricity and stock variable

$X = X(E,\ S)$ .... Eq. 1

Equation (2) in utility function based on electricity consuming good X and other good Z with demographic D and geographic G variables;

$U = u(X(E,\ S), Z; D, G)$ .... Eq. 2

Equation (3) is nonlinear budget constraint, where other goods have numaire price and electricity consuming goods have prices P_x ;

$P_x X + 1Z \leq Y$ .... Eq. 3

For the optimal solution cost for producing commodity X is minimized subject to the technology function;

$Min(P_x X + P_z Z)\ \ subject\ to\ X = X(E, S)$ .... Eq. 4

Optimum cost for producing given level of output of commodity (minimized cost for the good X);

$C = C(P_E\ , P_S\ , X)$ .... Eq. 5

Form the cost function we can get the input demand function by applying the Shepherd lemma with respect to both input prices;

$E = \frac{\partial C(P_E\ , P_S\ , X)}{\partial P_E} = E(P_E\ , P_S\ , X)$ .... Eq. 6

$S = \frac{\partial C(P_E\ , P_S\ , X)}{\partial P_S} = S(P_E\ , P_S\ , X)$ .... Eq. 7

Then the next step is the second method of optimization. In this step utility function is maximized with respect o non linear budget constraint;

$Max\ u(X(E,\ S), Z; D, G)\ \ subject\ to\ \ C(P_E\ , P_S\ , X) + P_z Z \leq Y$ ...... Eq. 8

$L = u(X(E, S), Z; D, G) + \lambda(Y - C(P_E\ , P_S\ , X) - P_z Z)$ ..... Eq. 9

The partial derivation with respect to both variables X and Z are taken for the purpose of getting optimal bundle of good X and Z that will maximize the household utility;

$$\frac{\partial L}{\partial X} = \frac{\partial u(X(E, S), Z; D, G)}{\partial X(E, S)} - \lambda P_x \leq 0$$
$$\frac{\partial L}{\partial Z} = \frac{\partial u(X(E,\ S), Z; D, G)}{\partial Z} - \lambda P_z \leq 0$$

For the making analysis more simple it is assumed the consumer will spend his all income on these two goods and save nothing so we used the equality in the constraint function that results as follow:

$$\frac{\partial u(X(E,\ S), Z; D, G)}{\partial X(E, S)} - \lambda P_x = 0\ , \qquad \lambda P_x = \frac{\partial u(X(E,\ S), Z; D, G)}{\partial X(E, S)}$$
$$\frac{\partial u(X(E,\ S), Z; D, G)}{\partial Z} - \lambda P_z = 0\ , \qquad \lambda P_z = \frac{\partial u(X(E,\ S), Z; D, G)}{\partial Z}$$

The optimal demand for good X is equal to the X^* and for Z is Z^* which are the function of the household income, the input prices and demographic and geographic variables;

$X^* = X^* (P_E, P_S, Y, Z; D, G)$ .... Eq. 10

$Z^* = Z^* (P_E, P_S, Y, Z; D, G)$ .... Eq. 11

For getting maximum utility household need to used optimal commodity bundle X^* and Z^*. There are two input demand function from the cost function in equation 10 and 11 respectively. By putting the value of X in input demand functions;

$$E = E(P_E, P_S, X^* (P_E, P_S, Y, Z; D, G)$$

$E = E(P_E, P_S, Y, Z; D, G)$ .... Eq. 12

$$S = S(P_E, P_S, X^* (P_E, P_S, Y, Z; D, G))$$

$S = S(P_E, P_S, Y, Z; D, G)$ .... Eq. 13

By simple optimizations of utility function we have got optimal bundle of electricity demand (input demand) function;

$E = E(P_E, P_S, Y, Z; D, G)$ .... Eq. 12

E = E(Y, HS, DW, Appliances, L_appliances)

The study has the general form of function, known as it derived demand of residential electricity for a household because we are directly getting utility from good X* and the Energy (E) is used as input demand for the good X*. For estimation, the model is transformed into to following:

$ln\ \_e = \alpha + \beta_1 lnY + \beta_2 lnHS + \beta_3 lnDW + \beta_4 D + \mu$ .... Eq. 13

where $ln\ \_e$ is lof of electrcity consumption, lnY represents log of monthly household income, $lnHS$ indicates log of household size, $lnDW$ represents log of dwelling size, and D dummy variable capturing the presence of appliances in the household.

Data

A dataset is extracted from Household Integrated Economic Survey (HIES) 2010-11 – a nationally representative data collected by Pakistan Bureau of Statistics (PBS) which covers 16,341 households in all urban and rural areas of the four provinces and Islamabad excluding military restricted areas. This study employs a two-stage stratified sample design; the selection of Primary Sample Units (PSU) and Secondary Sample Units (SSUs) are discussed in Table 1. Table 1 indicates the entire sample of households has been drawn from 1, 180 primary sample units (PSUs) out of which 564 are urban and 616 are rural.

Table 1
Sample Distribution

Province/Area	Sample PSUs			Sample SSUs		
	Urban	**Rural**	**Total**	**Urban**	**Rural**	**Total**
Punjab	256	256	512	2935	4019	6954
Sindh	152	144	296	1802	2296	4098
Khyber Pakhtunkhwa	88	120	208	1041	1913	2954
Baluchistan	68	96	164	811	1524	2335
Total	**564**	**616**	**1180**	**6589**	**9752**	**16341**

Source: Pakistan Bureau of Statistics (2015)

Description of Variables

This study is using five explanatory variables with its dependent variable Electricity unit consumption. The dependent variable is constructed through backward induction method (BIM) from the monthly electricity unit consumption. The variable " uc " electricity consumption is the dependent variable and shows the total units consumed by the household of Pakistan for the period 2010-11. The construction process of the dependent variable is as follow:

In Step 1, the electricity consumption expenditures are collected from HIES. In HIES, following information is available "Did household members consume any of the following items during the last 1 month? The item list includes Electricity with code 2707. The respondent replies with the amount household pay during the last one month". This provides monthly electricity expenditures.

In Step 2, we gathered the information about the tariff rates for the fiscal year 2010-11. These rates are given in slabs consisting of five different rates for household electricity consumption. Tariff rates consist of five slabs including the tariff rate for units 0-50 is 1.87, 50-100 rate is Rs. 4.45, from 101-300 rate is Rs. 6.73, 301-700 rate is Rs. 10.65 and for all units above 700 the rate is Rs. 13.29. These rates are taken from the electricity bill for the month of March 2011. With the help of BIM, the total units consumed by household are generated from his electricity expenditure.

Monthly Expenditure = E_i $\quad i = 1,2,3,\dots,N$

Electricity Unit Price = P_{ij} $\quad j = 1,2,3,4,5$

Monthly Electricity Unit Consumption Expenditure = $\frac{E_i}{P_{ij}}$

N = Total observation

i = households

j = slab rates

This method provides unit actual units consumed by each household. Table 2 provides the detailed description of all variables used in the study[2]:

[2] Appendix table A provides the descriptive statistics of all variables

Table 2
Description of Variables

Variables	Code	Definition
Monthly Electricity units consumed	**UC**	The dependent variable is log of monthly unit consumption of electricity. This variable is generated through BIM by using monthly electricity expenditure and available tariff rates: Continuous (number of electricity unit consumed)
Monthly Household Income	**Y**	This variable is log of the monthly income of household: Continuous (total income)
Household Size	**HS**	Total number of person in the household (log): Continuous (number)
Dwelling Size	**DS**	This variable is log of number of rooms available in a house.
Appliance	**APP**	This is dummy variable which indicates 1 if anyone of all appliances is present with household and 0 otherwise (Appliances = Electric Iron, Sewing machine, Television, Burner, Washing machine)
	LAPP	This is also a dummy variable which indicates 1 if anyone from luxury appliances (vcp, refrigerator, air cooler, air conditioner, computer and cooking range) is present with household and 0 otherwise.
Province	**PRO**	Provincial dummies. KPK is used a reference category Following dummies are used: Punjab (1 if yes otherwise 0) Sindh (1 if yes otherwise 0) Balochistan (1 if yes otherwise 0)
Region	**REG**	Regional dummies: (1 for Urban and 0for Rural)

To estimate the proposed model, the validity assumption of simple Ordinary Least Square (OLS) is validated; however, the fourth assumption $\sum u_i x_i=0$ does not hold. The household monthly income is highly correlated with undefined factors influencing the residential electricity demand. The results of OLS estimator are not consistent and best linear unbiased estimators (BLUE)[3]. Hence, for consistency of results; the study needs a valid instrument for estimation that can be achieved by using Two Stage Least Square (TSLS/2SLS) or Generalize Method of Movement (GMM) instead of OLS (Arbués, Garcıa-Valiñas, & Martınez-Espiñeira, 2003). Mostly in panel data analysis where researchers use more than one instruments for endogenous variables, and instruments are weak; this would create over- or under-identified model problem (Dubin et al., 1984; Filippini, 1999; Nieswiadomy et al., 1989). In this vein, this study focuses on 2SLS because single instrument for endogenous variable and data is cross sectional (Filippini & Pachauri, 2004; Shi, Zheng, & Song, 2012).

For the selection of the instruments, there are two basic conditions to be met namely the instrument relevance and the endogenity of the instrumental variable with explanatory variable (Stock & Watson, 2011). This study uses food expenditure as an instrument because food expenditure indicates household income but complete uncorrelated with error term of this model. The instrument relevance is basically the relationship of the instrumental variable with the endogenous variable (Dilaver & Hunt, 2011; Reiss & White, 2005). If there is a strong relationship between income and food expenditure; it shows that the instrument is also

[3] Stock, James H., and Mark W. Watson. "Instrumental Variable Regression." *Introduction to Econometrics*. Boston: Addison-Wesley, 2011. 422.

strong[4]. The process of testing instrumental relevance is to regress the endogenous variable on instrumental variable as in equation 14 and check whether parameter of this regression model is significant or not. The estimating equation 14 has can be written as;

$$lny = g(fe) + v^{*} = \varphi + \gamma \ln \ln (fe) + v^{*} \ldots\ldots\ldots\ldots\ldots \quad \text{Eq. 14}$$

Null and Alternative Hypotheses:

$H_0: \gamma = 0$ (Instrumental variable is not relevant with endogenous variable)

$H_1: \gamma = 1$ (Instrumental variable is relevant with endogenous variable)

$Test\ Statistics: \hat{t}_{\gamma} = \frac{\hat{\gamma}-\gamma}{SE(\hat{\gamma})} = \frac{0.88-0}{0.0074} = 118.52;\ t -$ Critical value = $\pm$ 1.96

As the result represents the absolute value of t-calculated is greater than the absolute critical value, so the null hypothesis can be rejected and the instrumental variable is highly relevant with endogenous variable. Next, the endogenity of the instrumental variable is checked. The household income variable is endogenous because it is correlated with error term as well as it affects the other variables as well. In most of the studies, the endogenity problem has been encountered in the literature because income is directly affecting the economic agent. For instance, by increasing the income of the household appliances, the dwelling size and other factors will also be affected through household income. Food expenditure is used as the instrument for household income and the results show food expenditure is a strong instrument because there is no relationship between the error term and food expenditure and also no relation with other variables of the model but it significantly explains the variation in error term.

Results and Discussion

Household income has positive significant impact over the residential demand for electricity (Deaton, 1980; Branch, 1993; Fell et al., 2014; Filippini & Pachauri, 2004; Zhou & Teng, 2013). In urban sector (0.434) is more responsive to their income than the rural sector (0.212) because in city as the income of the household increase, their consumption increases rapidly as compare to rural. This indicates that the urban population is more trends oriented than the rural population. But luxury appliances affect rural sector (0.293) more than urban (0.203) because electricity consumption is more in urban sector than in rural. So in relative terms the a very small changes in luxury appliances have more positive significant impact in rural sector then urban because they have less demand as compare to urban (Burney et al., 1990; Nasir et al., 2008; Chaudhry, 2010; Khattak et al., 2010). Household size has negative significant impact in rural sector (-0.0857) that contradict the common results. In this case as we are considering monthly electricity demand for household, so as the average number of household increase their per person average share in electricity consumption decrease that is why the result of this study has appeared with negative sign (Gibson, 2003; Leticia et al., 2012). At overall level all results are consistent with the previous studies except household size.

[4] For the detail of endogenity comprehensive work is given in the book basic econometric by Gujarati (Nawaz et al., 2014)

Table 3
Residential Electricity Demand for Pakistan

Variables	Overall	Urban	Rural
Household Income	0.379***	0.434***	0.212***
	(0.0155)	(0.0193)	(0.0271)
Household Size	-0.103***	-0.0857***	-0.0282
	(0.0131)	(0.0178)	(0.0199)
Dwelling Size	0.0430***	0.0440**	0.0700***
	(0.0120)	(0.0171)	(0.0163)
Appliance1	0.216***	-0.158	0.241***
	(0.0574)	(0.195)	(0.0582)
Appliance2	0.275***	0.203***	0.293***
	(0.0117)	(0.0161)	(0.0157)
Constant	1.115***	0.989***	2.537***
	(0.155)	(0.264)	(0.250)
Observations	13,913	6,206	7,707
R-squared	0.211	0.235	0.130

Note: Robust ***, ** and * represent 1%, 5% and 10% significance level respectively.

Household income has positive significant impact over the residential demand for electricity in all provinces of Pakistan that shows electricity is normal good for Pakistan. But this response is largest for Sindh population, then Punjab NWFP and Baluchistan with their income elasticities 0.487, 0.470, 0.406 and 0.380 respectively. As the income of the household increases, he uses more comforts of life and use of electricity will increase. The demand elasticity with respect to income is positive according to economic theory (Deaton, 1980; Branch, 1993; Fell et al., 2014; Filippini & Pachauri, 2004; Zhou & Teng, 2013). This indicates in Sindh, as the income of the household increase, their consumption increases rapidly as compare to other provinces. The second major determinant of the residential demand for electricity is luxury appliances that have also positive and significant impact over the residential demand for electricity all over the country (Burney et al., 1990; Nasir et al., 2008; Chaudhry, 2010; Khattak et al., 2010). In Punjab luxury appliances have largest impact with beta coefficient 0.212 over the other provinces Sindh, NWFP and Baluchistan with beta coefficients, 0.193, 0.171 and 0.0464 respectively. So in relative terms a very small change in luxury appliances has more positive significant impact in Punjab than other province. Household size has negative significant impact in all the provinces that seems to contradict the common results. But in this case as we are considering monthly electricity demand for household, so as the average number of household increase their per person average share in electricity consumption decrease that is why the result of this study has appeared with negative sign (Gibson, 2003; Leticia et al., 2012). At overall level all in all provinces the empirical findings are consistent with the previous studies except household size.

Table 4
Residential Electricity Demand for Pakistan by Province

Variables	Punjab	Sindh	NWFP	Baluchistan
Household Income	0.470***	0.487***	0.406***	0.380***
	(0.0216)	(0.0275)	(0.0493)	(0.0369)
Household Size	-0.0570***	-0.183***	-0.0702**	-0.0649**
	(0.0204)	(0.0217)	(0.0353)	(0.0309)
Dwelling Size	0.0316*	0.152***	-0.0400	0.0505
	(0.0166)	(0.0254)	(0.0329)	(0.0314)
Appliance1	-0.176	-0.113	0.769***	0.0915
	(0.140)	(0.0863)	(0.101)	(0.0970)
Appliance2	0.212***	0.193***	0.171***	0.0464*
	(0.0185)	(0.0234)	(0.0309)	(0.0255)
Constant	0.658***	0.396	0.351	0.910**
	(0.246)	(0.262)	(0.460)	(0.355)
Observations	6,177	3,564	2,445	1,727
R-squared	0.220	0.302	0.084	0.107

Note: Robust ***, ** and * represent 1%, 5% and 10% significance level respectively.

Conclusion

Electricity issue is the major issue for an economy because most of the economic activities are indirectly linked with it. The electricity shortfall causes the mental disturbance and inefficiency in the productivity. The objective of the study is to estimate the residential demand for electricity of Pakistan at national and sub-national level. In this research the five major variable household monthly income, household size, dwelling size, appliances and luxury appliances are chosen for determining the residential electricity demand for Pakistan. While analyzing the income elasticity, the strong empirical evidence is found that the household income of the Pakistani resident has positive significant response towards the residential elasticity of demand. The coefficient of income elasticity of demand shows almost equal responsiveness across the region. That results that the income elasticity of electricity demand remained almost same for the different income groups.

To control the problem of endogenity and heterscedaticity in the econometric model, this study used Robust TSLS method to make analysis simple and to get consistent estimators for the study. The estimated coefficients of household income, luxury appliances have shown positive significant impact and remained consistent with the economic theory at national and sub-national level. Whereas the study revealed the household size has negative significant effect over the electricity demand at national and sub-national level except the rural region. The remaining two variables, appliances and dwelling size have positive significant impact that is consistent with the economic theory or insignificant impact over the residential demand for electricity in Pakistan. In the context of Pakistan, the results of this study show the residential demand for electricity is highly elastic with income. Hence, there is a need to continually increase supply of electricity; this study suggests the policy makers in Pakistan should device strategies to enhance supply of electricity on regular basis. Additionally, residential demand for electricity in Pakistan is relatively more elastic to luxury appliances than necessities appliances; thus, the findings imply there is a pressing need to rationalize the policy toward it. The authorities should encourage the energy efficient appliances and restrain more energy consuming appliances by providing incentive to efficient appliance producer.

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