© *The Pakistan Development Review*
52:4 Part I (Winter 2013) pp. 375–403

What Inspires Electricity Crises at the Micro Level: Empirical Evidence from Electricity Consumption Pattern of Households from Karachi

LUBNA NAZ and MUNIR AHMAD

1. INTRODUCTION

With urbanisation[1] and modernisation of the economy, the use of electrical appliances has increased manifold in Pakistan. Now, household shares in the total electricity use account for 46.5 percent. While other users have lower shares that are industrial 27.5 percent, agriculture 11.6 percent, commercial 7.5 percent and the government 6.2 percent only [Pakistan (2012-13)]. Overtime, the household electricity consumption has also increased because of the increase in electricity consumers[2] and of village electrification.[3] Other important reasons include the use of modern appliances including both locally made and smuggled and increase in the share of urban women in the labour force by 6.5 percent during 2007-08 and 2012-13 [Pakistan (2012-13)]. These reasons are also responsible for enlarging electricity demand and supply gap over the years and have led to the electricity shortage to alarming proportions in March 2012. The electricity gap increased to 57,754 GW from 56,930 GW showing an increase of 1.4 percent from the corresponding period of the last year. The acute electricity shortage has caused long hours of the electricity load shedding in the country. The population living in urban areas bears the direct fall out of the electricity breakdown because of the modern lifestyle and sheer dependence on electricity [Pakistan (2012-13)].

Karachi is the largest city of Pakistan and the fourth largest urban centre of the world. It is located at the elevation of 65 meters above sea levels. It has the largest urban population (20 million) in Pakistan comprising locals, internal migrants and even external migrants mainly from Bangladesh and Afghanistan. Karachi is administratively divided into five districts, eighteen towns and six cantonments. The city's management is run

Lubna Naz <lubnanaz@uok.edu.pk> is PhD scholar, Pakistan Institute of Development Economics, Islamabad. Munir Ahmad <munir@pide.org.pk> is Joint Director, Pakistan Institute of Development Economics, Islamabad.

[1]Urban population increased from 58.78 million in 2008-09 to 69.87 million in 2012-13. It is projected to reach at 122million by 2030 given the current pattern of urbanisation continues [Pakistan (2012-2013)].

[2]On average, electricity consumers in household sector increased at the rate of 20.8 percent per annum during 2007-08 and 2012-13 [Pakistan (2012-13)].

[3]8995 more villages were electrified from June 2012 to March 2013 [Pakistan (2012-13)].

largely by local government .The city has top ranking in almost all social and economic indicators among 110 districts of Pakistan [Haroon and Khan (2007)]. Karachi Electric (K-electric)[4] is responsible for supplying electricity to entire Karachi including its suburbs and some parts of Balochistan. In total, it caters to the electricity demand of 20 million consumers.[5] Now, households in all five districts of Karachi are suffering from power breakdowns due to an acute shortage of electricity, dwindling power distribution and poorly managed transmission lines of the K-Electric.[6] The electricity demand of Karachi increased to 2500 MW in 2013 and surpassed 2700 MW in the peak of summer (Jun 2013) causing load shedding of up to 14 hours daily for residential consumers.[7]

With this background, the present study has set two main objectives:

First**,** to empirically analyse the end use based electricity demand for the residents of Karachi. The study employs Conditional Demand Model (CDM), which is a multivariate econometric technique. It uses information on household's total electricity consumption, electricity pricing, weather and household details on holding of modern appliances stock. The model yields robust end-use estimates for energy consumption of different appliances after accounting for difference in electricity consumption.

Second, to assess economic and social impacts of the electricity crises on the households by gender and the district of residence, and the household's ability to cope with electricity crises in the short run. Also, to analyse the household's views on prevailing electricity crises and its impact on work, medical and other expenses, crimes, participation in ceremonies, etc. For this, the study uses logistic regression and employs a qualitative research method.

Earlier studies [see for example Parti and Parti (1980); Aigner, *et al.* (1984); Lafrance and Perron (1994); Bartels and Fiebig (2000)] used CDM to estimate end use based electricity demand. In the recent past [for example Hsiao, *et al*. (1998); Larsen and Nesbakken (2004); Yun and Steemers (2011)] have used Engineering Model end-use meter data to estimate end use based electricity consumption. A few studies [for example Lafrance and Perron (1994); Bartels and Fiebig (2000)] used various time periods to determine the causes of changes in the pattern of electricity consumption. However, these studies could not use gender-based differences in the analysis of end-use electricity consumption. Thus, it is important to analyse gender specific differences in end-use electricity demand. In addition, the analysis of gender-specific differences in the ownership of electrical appliances and socio-economic characteristics of the head of the households also helps to analyse various implications of electricity shortfall.

The findings of the study suggest electricity demand depends on end-use electricity consumption in Karachi, and income, household size and dwelling type interact with end-use of electricity consumption. Furthermore, households with

[4]K-electric is presently a private limited company established in 1913 under the Indian companies act of 1882. It was privatised in 2005 and renamed on 20th February 2014 as K-electric from KESC. It is also only vertically integrated company that supplies electricity to Karachi and some parts of Balochistan.

[5]www.ke.org.pk

[6]A/c to K-electric the transmission and distribution losses stood at 27.8 percent in 2013, see for details http://www.ke.com.pk

[7]See The Express Tribune, published on May 14, 2013. Available from http://www.tribune.com.pk

inadequate capacities to cope with electricity crises are more vulnerable to electricity crises than households who can afford alternate provisions. Above all, gender, income, district of residence and the electricity saving behaviour of the head of household also determine the vulnerability to electricity crises at the household level.

The next section reviews methods relating to analysis of electricity demand and electricity shortfalls. The methodological framework for end use electricity demand and econometric specification of the determinants of the electricity crises is then outlined. The next section presents results and discussion on household's views about electricity crises, its contributors, its implications and the government's ability to handle the problem. The last section highlights gender-specific differences in coping with electricity crises, followed by the conclusion of the study and suggestions for policy-makers.

2. METHODS

2.1. Review of Research on Electricity Demand

The existing research work on electricity consumption suggests two fundamental demand-side approaches for electricity demand analysis; that is utility maximisation or cost minimisation and end use electricity consumption. The former approach uses cross-section, time series and panel data methods to obtain theoretically consistent estimates of electricity demand [see for example, Kraft and Kraft (1978); Dubin and McFadden (1984); Jumbe (2004); Yoo (2006); Jamil and Ahmad (2010); Ahmad, *et al*. (2011)]. The latter approach employs econometric methods that are CDM and Engineering Model [see for example, Parti and Parti (1980); Lafrance and Perron (1994); Larsen and Nesbakken (2004); Yun and Steemers (2011)].

Moreover, we can distinguish studies based on end-use electricity consumption by two main methods; the first method is called the conditional demand model (CDM) and the second method is termed as the Engineering Model. The earlier studies, for example, Parti and Parti (1980), Aigner, *et al*. (1984), Lafrance and Perron (1994), Fiebig and Steel(1994); Bartels and Fiebig (2000) and Dalen and Larsen (2013) used the former method of electricity demand. The studies based on the former method use household's total electricity consumption, electricity prices, weather, household's ownership of energy appliances and a household's demographic and economic characteristics to model electricity demand. These studies mainly differ in the sample period covered, as some of the studies [for example, Lafrance and Perron (1994); Bartels and Fiebig (2000)] used many periods to analyse patterns of electricity consumption. The studies based on Conditional Demand Model (CDM) have an advantage over the Engineering Model because of complexity of the latter approach to adjust electricity demand mainly for regional differences in income, prices and energy-saving behaviour.

Recent studies, for example, Hsiao, *et al.* (1998), Larsen and Nesbakken (2004), Reiss and White (2005), Firth, *et al.* (2008), Yun and Steemers (2011) used Engineering Model. This method is an improvement on the first in respect of employing end-use metered data on electricity consumption of households and yielding results that are more robust. However, the study based on engineering model uses direct meter data and so imposes a significant cost on the household. Many developing countries like Pakistan have not switched to end-us electricity meters yet. Therefore, researchers cannot use the engineering model to estimate electricity demand.

In Pakistan, the literature on electricity demand can be classified into three groups. The first group comprises studies that estimate electricity by using economic theory[8] and explore its determinants. These studies include: Siddiqui (1999, 2004), Aqeel and Butt (2001), Khan and Qayyum (2008), Khan and Usman (2009), Nasir, *et al*. (2009), Jamil and Ahmad (2010) and Shahbaz and Feridun (2011).[9] A few studies used total electricity consumption in kWh as dependent variable, and electricity prices and per-capita income as main explanatory variables [for example, Aqeel and Butt (2001); Nasir, *et al*. (2009); Alter and Syed (2011)]. Others for example [Jamil and Ahmad (2010); Siddiqui, *et al*. (2004); Shahbaz and Feriden (2011)] have analysed electricity demand at sectoral levels. The studies differ in the use of econometric techniques, sample periods, independent variables and decomposition of electricity demand into commercial, industrial and household.[10] The findings are mostly consistent with economic theory[11] [for example, Jamil and Ahmad (2010)] except for few studies[12] [for example, Khan and Quyaum (2009)] which contradict the theory.

The second group includes research conducted more recently about the causes and consequences of electricity shortages in Pakistan. These studies are addition to the literature as electricity crises deepened in 2007-08 and reached at peak in 2011 when electricity shortfall exceeded 40 percent of national demand [FODP (2010)]. The studies include: FODP (2010), Malik (2012), Asif (2011), Trimble, *et al.* (2011), Nasir and Rehman (2011), Alhadad (2012), Qasim and Kotani (2013) and Pakistan (2013). The research reveals that rapid growth of electricity demand, inadequate electricity generation capacity and lack of alternate energy sources have largely contributed to intensify present electricity shortfall. Other reasons given include inconsistent power policy, issues with governance and circular debt [see for example, FODP (2010); Malik (2012); Alhadad (2012)].

On the other side, commonly noted consequences are fiscal burdening, as 7.6 percent of total government revenue was used for power subsidies in 2007-08, and decline in economic growth and dwindling growth of manufacturing. Besides, increasing trade deficit due to oil imports, delays in export's orders and decline in employment are also fallout of long-standing problem of electricity shortfall [see for example, FODP (2010); Nasir and Rahman (2011); Pakistan (2013)]. A third group of study deals with effects of electricity crises on industry's output, employment and delay in supply orders, and decline in commercial business [see for example, Pasha (2010); Siddiqui, *et al*. (2011)].

Two studies by Iqbal (1983) and Saleem (1992) are different from earlier studies as authors used different methods from the earlier work on electricity demand in Pakistan. Iqbal

[8]Utility maximisation approach is used to derive electricity demand and time series econometric techniques i.e. Cointegration, Autoregressive and Distributed Lag model, Granger Causality etc. are used for estimation of electricity demand.

[9]See table at the end of Section 3 for details.

[10]Aqeel and Butt (2001) analysed relationship among different sources of energy and economic growth, Siddiqui (2004) analysed the relationship between commercial sector electricity demand and economic growth and Jamil and Ahmad (2010) analysed electricity demand at various disaggregations i.e. sectors level.

[11]Electricity demand is price inelastic and income elastic in long run [Jamil and Ahmad (2010)], Electricity demand is price and income inelastic [Khan and Usman (2009)].

[12]Electricity demand is price and income elastic in the short and long run [Khan and Qayyum (2009)].

(1983) estimates fuel demand function conditioned on the stock of energy using appliances and their rate of use. The study showed negative price elasticity of fuel and positive income elasticity of fuel. Saleem (1992) uses cross-sectional data from Karachi on electricity consumption to find out the probability of electricity shortage conditioned on variation in temperature and projected the average and the peak electricity demand (see Table 1). Recently, Chaudhry (2010) analyses the impact of appliance ownership and household income under different tiers of electricity tariff on residential monthly electricity consumption of Lahore[13] for 2003. The study used five tariff tiers, which included Rs 1.675kWh for 50kWh or less, Rs 2.613 for 51kWh -101kWh, Rs 3.53kWh for 101kWh-300 kWh, Rs 5.87 for 301kWh- 1000kWh, Rs 7.047 for more than 1000kWh. The study showed positive relationship between electricity usage and exogenous variables i.e. income and ownership of electrical appliances. The study also showed that total ownership of electrical appliances was distributed across tiers, as households consuming in the fourth tariff tier owned most of air-conditioners, computers, and microwaves. To sum up, the existing research on electricity demand and on causes and implications of electricity shortages mainly differs in the use of methods as shown in Table 1.

This study adds to the existing literature in two ways. First, it estimates end-use based electricity demand for households in Karachi, and analyses household's holding of modern appliances with other characteristics as determinants of electricity crises. Second, it analyses difference in the ownership of electrical appliances by the gender of the head of households and implications of electricity crises at local levels.

2.2. Data Collection

This article is based on the household energy survey. The survey was conducted in all districts of Karachi in the last week of May 2013.[14] The simple random sampling technique was used and 2,500 households of various income groups were selected. A well-structured questionnaire was formed and emailed to more educated households. On the spot interviews were also conducted with uneducated households and with households who failed to return the questionnaire on-line. The questionnaire consisted of eight sections. These are personal information; job information; household's spending; electrical and gas appliances; electricity and gas load shedding; losses due to electricity and gas load shedding; household views about effects of electricity crises. In total, 2,333 filled questionnaires were received of which 110 questionnaires were found with matching cases. Similarly around 220 questionnaires were found with less than 50 percent responses and with responses missing on electricity billing, income, spending and assets. Only 2001 questionnaires were found with a 99.8 percent response rate. All information was collected at the household level. Head of the household was the main respondent, except few cases where the eldest son or daughter took part for the head. Data have also been collected using purposive sampling method. For this, in-depth interviews[15] of households' working members, students and voters[16] were also conducted

[13]The capital of the Punjab Province in Pakistan.

[14]The information on electricity consumption in kWh, electricity expenditures and prices were collected for March, April and May 2013 and on all other variables for May 2013. The Household Energy survey was conducted by the students of Adv. Economics Statistics, Department of Economics, University of Karachi under the supervision of the course in charge Lubna Naz (author).

[15]Open ended, and Close ended question such as yes or no and check were used.

[16]In Pakistan, only 18 years and above are eligible for casting vote in general election.

© The Pakistan Development Review
52:4 Part I (Winter 2013) pp. 375–403

Table 1

Summary of the Selected Studies on Electricity Demand and Implications of Electricity Crises

Authors	Period	Variables /Objectives	Methods	Main Results
Parti and Parti (1980)	1975	Household electricity consumption, stock of electrical appliances, household income and electricity price per kWh	Ordinary last square	Negative price elasticity of demand Positive income elasticity of electricity demand
Iqbal (1983)	1960-1981 Annual data	Household fuel consumption and Household Gas and Electric appliances, and temperature	Ordinary Least Square	Negative fuel price elasticity in the long run Positive fuel income elasticity in the long run
Dubin and McFadden (1984)	1975	Electricity consumption, stock of electrical appliances, income, dwelling type, household size	Ordinary Least square or OLS, Reduced form or RF, Instrumental variable or IV and Conditional Expectation Correction or CEC)	Own price elasticity of electricity demand is higher for OLS and IV, income elasticity of electricity is lower for OLS than other methods, and cross -elasticity of electricity demand with respect to gas price is higher in CEC than OLS.
Burney and Akhtar (1990)	1984-85	Household expenditure on energy, household size, income, age etc.	Ordinary Least Square	Rural Household Spend More on Fuel than Urban Households do. Price Inelastic Fuel Demand.
Saleem (1992)	2000	Household electricity consumption, weather, household characteristics	Ordinary Least Square	Changes in household electricity demand are conditioned on changes in temperature in Karachi.
Reiss and White (2001)	1993 and 1997 Two waves	Electricity consumption, electricity price, demographic and economic characteristics of household, energy appliances, heating degree days	Method of Moments	Price of electricity has diverse impact on appliance specific electricity use Income effect on appliance specific electricity use is negligible and statistically insignificant.
Larsen and Nesbakken (2002)	1990	Electricity consumption, ownership of electrical appliances, household characteris-tics, weather related variables, electricity prices etc.	Ordinary Least Square	The estimates of engineering model for space heating, cooking and water heating are higher than the estimates for the same from the conditional demand model.
Siddiqui (2004)	1971-2003	Electricity consumption and per-capita GDP.	Hsiao Granger Causality, ARDL	Lack of uniformity exists in the impact of all constituents of energy demand on Economic Growth. Only Electricity and some petroleum products have high impact on Economic Growth.
Jamil and Ahmad (2010)	1960-2008	Electricity Consumption, Electricity Prices and Income	Johnson cointegration	Growth in GDP causes Electricity Demand Growth in Commercial, Manufacturing and Agriculture sectors causes Economic Growth .
Chaudary (2010)	Panel data of 66 countries for 1991-2009	Electricity Consumption, Electricity Prices and Real GDP	Panel Data Models; Fixed Effects and Pooled Regression	Positive Income Elasticity of Electricity demand. Negative Impact of Electricity Prices on Manufacturing Sector's growth.

Continued—

Table 1—(*Continued*)

Malik (2010)		Causes and Consequences of the Electricity Shortages in Pakistan.	Quantitative Analysis	Poor Governance is the main cause of prevailing electricity crises.
Siddiqui (2011)	1971-1997	Determinants of Energy Demand and Revenue Generating Impact of Changes in Energy Prices.	Regression Analysis	Negative Price Elasticity of Energy Positive Income Elasticity of Energy .
Alter and Syed (2011)	1970-2010	Electricity prices, real GDP, number of Electricity Consumers & Electric Appliances	Johnson cointegration	Long run relationship exists between Electricity Consumption and Prices.
Shahbaz (2011)	1971-2009	Real GDP per capita, real domestic private sector credit, electricity consumption	ARDL	Long run cointegration exists among Financial Development, Electricity Consumption, Labour and Economic Growth.
Shabaz and Feridun (2011)	1971-2008	Electricity Consumption and Per Capita Real GDP.	Autoregressive Distributed Lag Model or ARDL	Economic growth causes Demand for Electricity and not vice versa.
Alhadad (2012)		Introduced integrated Energy Planning & Policy information as tool to resolve Energy Crises	Analytical and Quantitative	Lack of integrated Energy planning or IEP is the main cause of persisting electricity crises.
Pasha, *et al.* (2010)		Impact of Electricity short fall on Industrial Sector.	Analytical and quantitative	Power Shortage in Industrial Sector alone has attributed in the loss to Economy over 2.5 percent of GDP.
Javed and Awan (2012)	1971-2008	Real per capita GDP and Electricity Consumption.	Engle and Granger Two Step Procedure.	Unidirectional causality runs from Electricity Consumption to Economic Growth. Electricity Shortages limits Economic Growth.
Ali, Iqbal and Sharif (2013)	1990-2010	Electricity Consumption and Maximum Temperature Index.	ARIMA Time Series Forecast Model for temperature Index	Maximum Mean temperature and Socio-economic Factors affect positively Electricity Demand.
Dalen and Larsen (2013)	1990,2001,2006	Electricity consumption, ownership of electrical appliances, household characteristics etc.	Ordinary least Square	Year to year changes take place in the Electricity consumption for washing, refrigeration and heating.

© *The Pakistan Development Review*
52:4 Part I (Winter 2013) pp. 375–403

Table 2

Description of Variables

Variables	Meaning and Evaluation
Electricity consumption	Total electricity consumption measured in kWh
Electrical-Appliances	Television, Deep-Freezer, Iron, Washing- Machine, Air- Conditioner, Tube-Lights, Water-Extracting-Motor, Desktop, Dryer, Refrigerator, Air-cooler, Microwave-Oven, Cell-Phone,
Electricity prices	Electricity price per kWh
Electricity expenditure	Monthly household outlays on electricity
Electricity load shedding	Electricity breakdown
Duration of electricity load shedding	No of hours electricity load shedding took place during March-May 2013
Timing of Electricity load shedding	No of hours electricity load shedding occurred in day and night during March-May 2013
Marital status	Married=2,Unmarried=2 Divorced or Divorcee =3, Widow or Widower=4
District	East=1,West=2, South=3, Central=4, Malir=5
Age	Age in years
Education	No-education=1 Primary=2, Matric=3, Intermediate=4, Graduation =5, Post-Graduation =6, Diploma=7
Gender	Male=1, Female=2
Household size	No of household members
No of dependents	Household members who are above 60 years age and below 10 years
Family unit	One person family=1, Two person family=2, Three person family=3, Four or more members family =4
Job status	Private job=1, Own-business=2, Government job=3, No job=4
Real Total expenditure	Sum of food and non-food expenditures deflated by official General Consumer Price Index of base 2007-08 for May 2013
No of lighting spots	No of lighting spots greater than ten =1, no of lighting spots fewer than ten =2
Dwelling type	Two or three room apartment=1, Four or more room apartment or house=2
Hot days	No of days for which maximum temperature >40 in March, April and May, 2013.
Crises Affected household (CAH)	Yes =1, No=2
Worst affected household (WAH)	Yes =1, No=2
Extent of electricity load shedding in last five years	Increase by multiple times=1, Increase=2, Decrease=3, No change=4
Increase in medical expenses	Yes=1, No=2
Government role in last five years	Yes=1, No=2
Street crimes during load shedding	Yes=1, No=2
Saving electricity	Yes=1, No=2
Household reaction to electricity load shedding	Media protest=1, Street protest=2, Passive=3
Impact on voting in general election 2013	Yes=1, No=2
Participation in ceremonies	Yes=1, No=2
Household's coping with Electricity load shedding	None=1, UPS=2, Genrator=3, Both=4
Daily Tasks:	
(a) Reaching office late	Yes=1, No=2
(b) Pick drop of kids to and from school	Yes=1, No=2
(c) Complying with doctor's employment	Yes=1, No=2

in every district. The household's views were gathered[17] about changes in the extent of electricity crises over the years, the role of government in addressing the problem of load shedding and household's reaction to load shedding. Other questions were asked about neighbourhood electricity theft, street crimes during load shedding, expenses on electricity alternatives and missed out important daily tasks (see Table 1). The data on non-heating and heating days were collected from the daily weather reports of the Pakistan Meteorological Department.[18] The information on electricity price per kWh was obtained from K-Electric.

2.3.1. *Methodological Framework for End-use Electricity Consumption*

This paper applies Conditional Demand Model (CDM)[19] on the data from household energy survey[20] to estimate end use based electricity demand. The econometric specification of the Conditional Demand Model (CDM)[21] is as follows

$$xij = \delta j + \sum_{m=1}^{M} \rho jm\left(Cim - \overline{Cjm}\right) + \mu ij \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (1)$$

Where x_{ij} refers to end-use electricity consumption for appliance j (j=1,2,…………K) of household i (xi, i=1, N) per period, C_{im} (m=1, 2, M) are economic and demographic variables for example age, household size, income, electricity prices, etc. $\overline{C_{jm}}$ is the mean value of these variables for households possessing appliance j. μ_{ij} is a stochastic error term. The parameter δ_j implies a mean value of electricity for end use j provided the household characteristics (Cim) relevant to end use j are equal for all households or ρ_{jm}=0 $\forall m$. Household characteristics such as education, marital status, gender, age, job type and income of the head vary across households. The second term on the right hand side of Equation (1) represents an adjustment in the end-use electricity consumption for appliance j due to the impact of economics and demographics of households. The Equation (1) can be estimated by the Ordinary Least Square, given the data have been collected on electricity consumption through end use electricity meters. For this article, the data on household electricity consumption in kWh is not based on end use electricity meters. Hence, the basic conditional demand model (CDM) given by Equation (1) cannot be estimated. However, the electricity consumption in kWh can be gathered over all end-use of electricity consumption in Equation (1) to get total electricity consumption in kWh of household i as x_i. As not all households own all types of modern electrical appliances, it is impossible to specify all end-use of electricity consumption. To account for heterogeneity in modern appliance ownership, a dummy variable, D_{ij}, is used to value one if household i own appliance j and value zero if the household does not own appliance j. Of J possible end-uses of electricity consumption, S shows electricity end-use demand that can be estimated separately, i.e. j=1, 2..., S,......., J and $S<J$. The econometric specification of the household conditional electricity demand is

[17]Close ended and open ended questions were used for collection of household's views about electricity load shedding and its impact on well-being of households.

[18]www.pmd.gov.pk

[19]Conditional demand model was estimated because directly metered data on end-use electricity consumption was not available for households of Karachi.

[20]This study uses sample of 2000 households for estimation after data cleaning.

[21]M. D. Hanne, Larsen, and M. Bodil (2013) Residential End-use Electricity Demand—Development Over Time. Statistics Norway, Research Department. (Discussion Paper No.736).

$$x_i \equiv \sum_{j=1}^{S} x_{ij} D_{ij} \equiv \sum_{j=1}^{J} x_{ij} D_{ij} + \sum_{j=S+1}^{J} x_{ij} D_{ij} = \sum_{j=1}^{J} \delta_{ij} D_{ij} + \sum_{j=S+1}^{S} \delta_{ij} D_{ij}$$
$$+ \sum_{j=1}^{J} \sum_{m=1}^{M} \rho_{jm} \left(C_{im} - \overline{C_{jm}} \right) D_{ij} + \mu_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Where, u_i is a stochastic error term and $u_i \approx$ NID (0, 1), which is given as

$$\sum_{j=1}^{J} \varepsilon_{ij} D_{ij} = u_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

The third term on the right hand side of the Equation (2) denotes economic and demographic variables as C_{im} and their mean values as $\overline{C_{jm}}$. These are interactions with electrical appliances to adjust electricity consumption for appliance *j*. For example interaction between household's dwelling type and number of tube-lights which a household owns captures the effect of household's dwelling type on the lighting consumption of electricity. We calculate interactions as deviations from average values of different household demographic and economic characteristics of households owning appliances for example $\overline{C_{jm}} = \frac{1}{H_j} \sum_{i=1}^{N} C_{im} D_{ij}$. The first term in Equation (2) $\sum_{j=S+1}^{S} \delta_{ij} D_{ij}$ shows unspecified electricity consumption. We assume that such consumption does not vary across households $\sum_{j=S+1}^{S} \delta_{ij} D_{ij} = x_0$. We also apply interactions to all *j* because unspecified end use electricity consumption depends on household demographic and economic characteristics. Further, we assume the coefficients of interactions are not varying across households .The final specification of the econometric model becomes

$$x_i = x_0 + \sum_{j=1}^{S} \delta_{ij} D_{ij} + \sum_{j=1}^{J} \sum_{m=1}^{M} \rho_{jm} \left(C_{im} - \overline{C_{jm}} \right) D_{ij} + \mu_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

x_i is total electricity consumption in kWh conditional on having appliances D_{ij} . It takes the value one if household i owns electric appliance j and zero if household i does not own appliance *j*. x_0 is unspecified household electricity consumption and δ_{ij} is the coefficient of the mean electricity consumption of appliances *j* held by the household *i* and for which D_{ij} has a value equal to one. To calculate estimates of mean electricity consumption for different electrical appliances of the average household, we multiply estimates of mean electricity consumption for each electrical appliance by the proportion of households holding electric appliance. The coefficient ρ_{jm} represents the consistency between interactions $(C_{im} - \overline{C_{jm}}) D_{ij}$ and electricity consumption x_i. C_{im} (m=1,2,3………M) are economic and demographic variables such as household's income;[22] household size; no of dependents; household energy saving behaviour; dwelling type; age, education, marital status and gender of the head of household . Also,

[22] Real total expenditures were used as proxy of income and income quintiles were computed. Real expenditures were computed by deflating total expenditure by the official General CPI for May 2013 and real expenditure was obtained for the base year 2007-08. Data on CPI is available from www.pbs.gov.pk.

days with temperature[23] <40^C are included as an explanatory variable (see Table 2), and $\overline{C_{jm}}$ is the mean value of the household demographic and economic characteristics. All variables on the right hand side in the Equation (4) are assumed to be exogenous. It is also assumed that no change has occurred in the stock of electricity using equipment during the survey period.[24] The Equation (4) is estimated by Ordinary Least Square or OLS.[25]

2.3.2. *Calculation of End Use Electricity Model*

The expected end-use electricity consumption for household i of appliance k is obtained from the Equation (5) as

$$E(x_{ik}) = \delta_k D_{ik} + \sum_{m=1}^{M} \rho_{km} \left(C_{im} - \overline{C_{km}} \right) D_{ik} \qquad \dots \quad \dots \quad \dots \quad \dots \qquad (5)$$

E is expectation operator. δ_k Shows difference in electricity consumption in kWh between households that own appliance $k, D_{ik} = 1$ or $\delta_k + \sum_{m=1}^{M} \rho_{km} \left(C_{im} - \overline{C_{km}} \right)$ and zero for those that do not own appliance or D_{ik} = 0. We calculate the average electricity consumption for end use k as

$$\hat{x}_k = \hat{\delta}_k \overline{D_k} + \sum_{m=1}^{M} \hat{\rho}_k \left(C_{im} - \overline{C_{km}} \right) \bar{D}_k \qquad \dots \quad \dots \quad \dots \quad \dots \qquad (6)$$

Equation (6) represents estimated parameters. Where $\bar{D}_k = \frac{1}{N} \sum_{i=1}^{N} D_{ik}$ is the mean value of the dummy variable for an appliance D_{ik} which a household owns. We calculate average electricity consumption on appliance k as average electricity consumption for a household that owns appliance k times the share of households in appliance ownership. The final estimated Equation is

$$x^p = \hat{x}_0 + \sum_{j=1}^{S} \hat{\delta}_k \overline{D_k} \qquad \dots \quad ... \quad \dots \quad \dots \quad \dots \quad \dots \qquad (7)$$

$\hat{x}_0$ is unspecified estimated electricity consumption, x^p implies predicted mean end use electricity consumption. We also calculate average actual electricity consumption of all households in the survey as follows,

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i \qquad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (8)$$

[23]The information on daily weather was obtained from www.pmd.org.gov for March, April and May 2013.

[24]The data was collected in May 2013; however, the information was collected on electricity consumption in kWh and electricity expenditure for March, April and May 2013.

[25]Ordinary Least square is Classical linear regression, it is based on certain assumptions i.e. homoskedasticity, normality, linearity, exogenity and no multicolinearity.

$\bar{x}$ is average actual electricity consumption. The share for electricity consumption of appliance *k* in total electricity consumption is calculated as follows

$$apl_k = \frac{x_k^p}{\bar{x}} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (9)$$

x_k^p is average electricity consumption for the appliance *k* and $\bar{x}$ is average of total electricity consumption. Finally, the share of unspecified electricity consumption is calculated in Equation (10).

$$S_{un} = 1 - \sum_{j=1}^{k} S_j = \frac{\hat{x}_0}{\bar{x}} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (10)$$

S_j is specified electricity consumption for appliance *j*, where $j = 1,2,\ldots..k$ and S_{un} denotes share of unspecified electricity consumption in the total electricity consumption. We calculate this as a residual of end-use electricity consumption after adjusting for all specified electricity end-uses.

2.4. Modelling Determinants of Electricity Crises

Crises affected households or (CAH) is the dependent variable, with either a "yes" or "no" response gathered from each surveyed household. We apply binary logistic model function as follows

$$P(Y = 1 | z_i \,.......\, z_k) = \frac{\exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j)}{1 + \exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j)} \quad \dots \quad \dots \quad \dots \quad \dots \quad (11)$$

In Equation (11) P_i shows the probability of getting affected by the electricity crises or $Y_{i=}1$ and (z_1………, z_k) are explanatory variable. They include economic, demographic and various dummy variables. The economic variables that affect the likelihood of getting affected from electricity load shedding are real income,[26] electricity prices,[27] ownership of modern appliances, job status and expenses on electricity. The household demographics used are the district; age, marital status and gender of the head; number of the working age household members, household size and number of dependents in the family (see Table 1). We also use dummy variables[28] for neighbour's electricity theft, district, households using alternative supplies during electricity load shedding, household saving electricity, and household protesting against load shedding, and model these dummy variables as independent in Equation (11), (see Table 1). The probability of not getting affected from electricity load shedding or $Y_i = 0$ is as follows

[26]The real expenditure of the households were computed by using data on official consumer price index for May 2013 from http://www.pbs.org.pk .

[27]Most of the electricity consumers (50 percent of the data) consume 300-700 units/kWh per month and hence pay 12.83 per kWh. information on electricity prices is available at http://www.ke.com.pk

[28]It takes value 1 if a condition holds and 0 if condition does not hold.

$$P(Y=0|z_i \,.......\, z_k) = 1 - \frac{\exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j)}{1 + \exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j)} = \frac{1}{1 + \exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j)} \qquad \ldots \quad (12)$$

To estimate parameters from the data set (y_i, z_{1i} ………z_{ki}) and i = 1,2………n, we assume that all or N samples are independent. The joint probability of the observed values (y_1 ……… y_i) is estimated as follows

$$P(y_1 \,..............\, y_n) = \Pi_{i=1}^{n} P(Y_i = y_i | z_{1i} \,...........\, z_{ki}) \qquad \ldots \qquad \ldots \qquad \ldots \quad (13)$$

Now we substitute Equation (12) and Equation (13) in place of each parameter on the right hand side of Equation (14). It gives the probability $P(y_1$ ……… $y_n)$ as an explicit function of known parameters (α, β_1, ……… β_k). The likelihood function for (α, β_1, ……… β_k) given (y_1 ……… y_i) is as follows

$$L(\alpha, \beta_1 \,........\, \beta_k | y_1 \,........\, y_n) = \Pi_{i=1}^{n}$$

$$\left\{ \left[\frac{\exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j}{1 + \exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j} \right]^{yi} \left[\frac{\exp(\alpha + \sum_{j=1}^{k} \beta_j Z_j}{1 + \exp \sum_{j=1}^{k} \beta_j Z_j} \right]^{1-y_i} \right. \qquad \ldots \qquad \ldots \qquad \ldots \quad (14)$$

If y_i = 1 it follows that 1 – y_i = 0 and the term in brackets reduces to Equation (1). Conversely, if y_i = 0 it follows that y_i = 1 and term in brackets then reduce to Equation (12). We estimate the Equation (14) to get maximum likelihood estimates of the logistic regression.

3. DESCRIPTIVE ANALYSIS

The summary statistics on household characteristics, ownership of electrical appliances, electricity consumption in kWh, electricity prices and weather conditions are shown in Table 3. The data collected on job status show that 56.40 percent of head of the household or interviewed persons have private jobs where only 5.35 percent are retirees or unemployed. Only 16.70 percent have government jobs while 21.50 percent are running their own business. The survey reveals that around 93 percent of female heads are in the job market and about 65 percent of female heads have private jobs (see Table 3). This infers that almost all interviewed female heads have some job.

The data show that about 36 percent of the household heads interviewed are graduates, and 31 percent of the household heads have a post-graduate qualification. The illiterate heads of the household are only 1.20 percent (see Table 3). The data show that about 86 percent of male heads and 55 percent of the female heads are married. While about 25 percent of the female heads are widowed or divorced and only 1.2 percent of the male heads were widower or divorcee (see Table 3). This implies that a majority of surveyed families are living with dependents.

As shown in Table 3, Almost all households had cell phones, television, iron, washing machine, refrigerator and lighting in Karachi in the survey period. However, a few households surveyed own air cooler, air-conditioners and microwave oven. Analysis

Table 3

Descriptive Statistics of Household Energy Survey 2013

Variables	All	Male	Female
Electricity consumption (kWh in 2nd quarter)	2076	1998	1950
Electrical Appliance Variables (0 or 1)			
Cell phone	0.99	0.99n/s	1.00n/s
Microwave oven	0.37	0.38n/s	0.34n/s
Television	0.98	0.97n/s	0.97n/s
Electric water pump motor	0.66	0.67*	0.56*
Dryer	0.38	0.37*	0.48*
Desktop	0.74	0.73***	0.78**
Washing machine	0.91	0.91**	0.97**
Iron	0.99	0.97	0.97
Refrigerator	0.93	0.93	0.98
Air cooler	0.24	0.21*	0.29*
Air conditioner	0.43	0.44*	0.39*
Electricity price (per kWh)	12.83	12.88	12.83
Deep freezer	0.23	0.24*	0.27*
Tube lights	0.99	0.99	1.00
No of lighting points>10	0.42	0.89*	0.82*
Other Variables (Interactions)			
Age of the head of household	43.9	44.40	40.37
Household size	4.5	4.5	4.0
Married head (0 or 1)	0.82	0.86	0.55
Energy saving household (0 or 1)	0.74	0.74*	0.79*
Two person household	.078	0.07	0.10
Flat ownership (0 or 1)	0.54	0.59*	0.66*
Single person household (0 or 1)	.025	0.03	0.01
At least 1 person over age 60 (0 or 1)	0.17	0.17	0.12
Dependency	0.23	0.22	0.19
Education of the Head of Households			
No education (0 or 1)	0.012	0.011	0.016
Matric (0 or 1)	0.14	0.14	0.10
Inter (0 or 1)	0.18	0.18	0.14
Graduation (0 or 1)	0.36	0.36	0.33
Post-graduation (0 or 1)	0.22	0.20	0.31
Diploma (0 or 1)	0.45	0.04	0.05
Primary (0 or 1)	0.036	0.036	0.034
No of days temperature>40	27	27	27
Job status of the head			
Private	0.56	0.55	0.65
Government	0.16	0.17	0.14
Own business	0.21	0.23	0.12
Retirees/unemployed	0.05	0.05	0.06

of appliance ownership by income groups[29] provides the reason for this disparity. Those in the higher strata of income have 79 percent more electricity using appliances like air-conditioners and microwave ovens. The data also show that household on average consume 688 kWh of electricity per month or 2076 kWh of electricity per quarter.[30] About 93 percent of households use electricity between 300kWh-700kWh per month and hence pay Rs 12.38 per kWh. The data from the daily weather reports show that recorded temperature in 27 days out of 92 days during March-May 2013 have remained more than 40^0C in Karachi.

We also use two-sample mean t-test to analyse the gender specific difference in the holding of electrical appliances and electricity consumption. The differences in the ownership of the stock of energy using appliances by gender of the head of the household are listed in Table 3. The data show no significant gender-specific differences in the pattern of the ownership of TV, electric water pump motor and iron. Similarly, the data show no gender-specific differences in electricity consumption in kWh and electricity charges per kWh a month. Nevertheless, the data show statistically significant differences in the ownership of specific electrical appliances like air-conditioners, desktop, dryer, number of lighting points, washing machine and deep freezer between male-headed and female-headed households. About 79 percent of female-headed households and 74 percent of male-headed households are inclined to electricity saving in Karachi, and gender-specific differences in conserving electricity are statistically significant. The data show that female-headed households own small dwelling size than male-headed households in Karachi as 66 percent female-headed and 59 percent male-headed households own small apartments (see Table 3). Figure 1 displays appliance ownership for all households and Figure 2 presents differences in the stock of modern appliances by gender.

Fig. 1. Average Energy Appliances Holding by Households

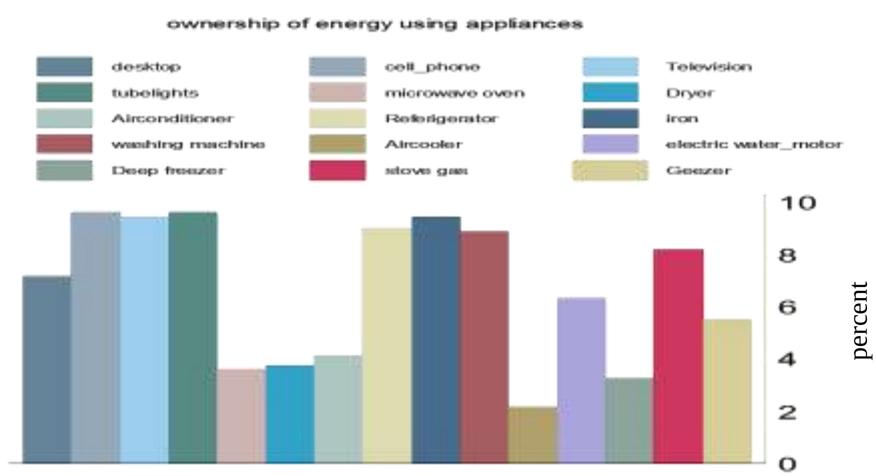
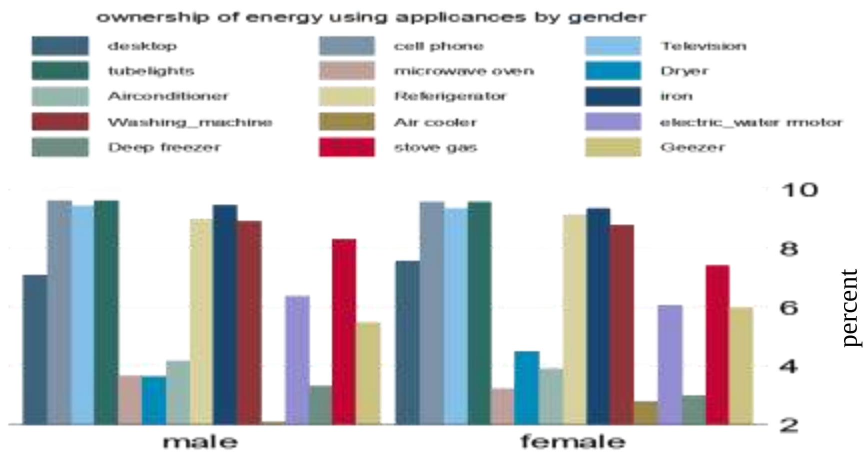


Fig. 2. Average Energy Appliances Holding by Gender

[29]Real total expenditures are used as proxy of income and income quintiles have been computed, results for income quintiles are not reported in Table 3.

[30]For March, April and May 2013.



3.1. Empirical Findings of Conditional Demand Model (CDM)

We use the Equation (4) to estimate end use based electricity demand for residents of Karachi. The estimates of conditional demand model (CDM) are given in Table 4. The quarterly estimate of electricity demand by air-conditioner is 1720 kWh, as 42 percent household own air-conditioners for cooling, this gives only 739 kWh for this cooling electric equipment for the average household. Almost all the households surveyed own iron and washing machine, this gives estimates for households having iron and washing machine, who use 386 kWh and 220 kWh. About 66 percent households use electric water motors for pumping water from pipelines. This indicates that households largely depend on electricity for water consumption in Karachi and electricity breakdown deprives them from water consumption.

The estimate of electricity consumption for more than ten lighting points is greater than the electricity estimate of lighting. The data show that only 42 percent households use more than ten lighting spots and 88 percent of these households belong to larger dwelling size and larger household size. This indicates that the larger family size and larger dwelling type both affect lighting consumption. The estimate of electricity consumption of a microwave oven is 406 kWh, which is even higher than a washing machine and air cooler. Since only 37 percent households own microwaves, the electricity estimate for households having this equipment equals to 150 kWh. Figure 3 illustrates quarterly estimates of electricity consumption for different appliances. The estimates of end-use electricity consumption in kWh for the preceding survey month (April 2013) are shown in Table 5. The electricity estimates for air-conditioner, washing machine and iron show similar patterns of consumption as we have found for these equipment for a quarter. The electricity estimates of lighting spots are higher than lighting and households that use more than 10 lighting points in the data set belong to larger household size and dwelling. The income of households interacts positively with the ownership of air-conditioners while non-heating days show negative interaction with air-conditioners (see Table 5). Only married household category interacts positively with

Table 4

Estimated Electricity Consumption (kWh per Quarter- 2013)

Variables [a]	Coefficient[31]	S/E	Mean-value	Assets Ownership
Intercept	172(2.20)*	78.21	000	000
Television	79 (2.51)*	31.24	77	0.97
Lighting	107(4.2)*	25.76	106	0.99
Desktop	69(2.09)*	33.03	56	0.74
Refrigerator	432(4.7)*	91.19	402	0.93
Deep-freezer	139(2.7)***	51.24	46	0.34
Iron	394(3.7)*	105.08	386	0.98
Air-conditioner	1720(51.60)*	33.33	739	0.42
Air-cooler	226(6.2)**	36.30	50	0.24
Dryer	93(2.9)**	32.68	36	0.38
Washing-machine	239(4.6)*	51.79	220	0.92
Microwave-oven	406(8.2)**	49.18	150	0.37
Electric water pump motor	107(3.5)*	30.87	71	0.66
No of lighting spots>10	219(4.91)*	44.26	92	0.42
Interaction Variables[b]				
High income*air-conditioner	443(4.6)*	96.01		
Household size*deep-freezer	241(4.7)**	51.12		
Household size*lighting	–191(-3.5)**	54.20		
One person household*refrigerator	288(3.8)*	74.78		
Two person household*water-motor	–126(2.06)*	60.08		
Non Heating degree days *AC	–42 (2.07)*	20.21		
Married head*microwave	49 (2.36)*	20.70		
Female headed households*air cooler	167.37(3.9)*	42.57		
Type of dwelling*lighting	–92(2.2)*	41.63		
R^2	0.41			
F-value	316.52(0.000)			
N-obs	2000			

Table 5

Estimated Electricity Consumption in kWh, April 2013

Variable	Coefficient	Standard Error	Mean-value	Assets Ownership
Intercept	63	10.11		
Television	21*	9.8	20	97.80%
Lighting	86*	17.48	86	99.14%
Desktop	26*	11.58	20	74.10%
Refrigerator	49*	20.20	45	93.35%
Deep-freezer	56*	16.97	19	33.90%
Iron	110*	35.26	107	97.90%
Air-conditioner	374**	11.03	159	42.90%
Air-cooler	72***	18.89	17	24.45%
Dryer	27**	11.21	11	38.80%
Washing-machine	76	18.79	70	92.20%
Microwave-oven	29**	10.64	11	37.50%
Electric Water pump motor	54	13.44	35	66.01%
No of lighting spots>10	122*	19.78	51	42.01%
R^2_adj	0.46			
F-value	304.02(0.00)			
N-obs	2000			

[31]*Note:* electricity estimates reported in Table 4 are based on robust regression (corrected for hetrosediasticty in variance); estimation has been carried out in Stata 11.

the use of microwave ovens. The family unit and specially two-person family show negative interaction with electric water pump motor in Karachi, and one-person family interact positively with refrigerator. The study does not find education of the head (any category), a district of the residence of the head, no of dependents, job type and age as statistically significant interacting variables with any of the electrical appliances. Figure 4 displays the mean value of electricity estimates for households.

Fig. 3. Mean Electricity Consumption Estimates in kWh per Quarter for Different Appliances

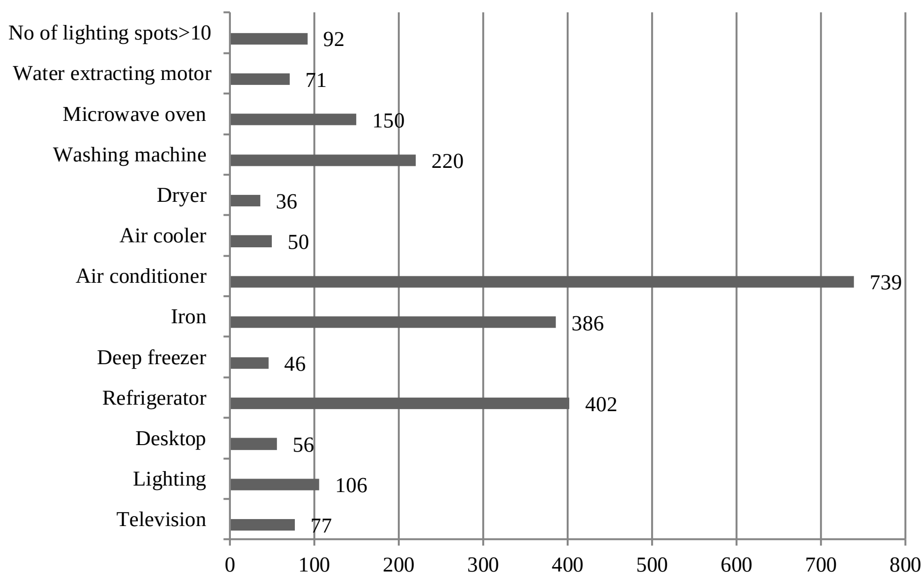
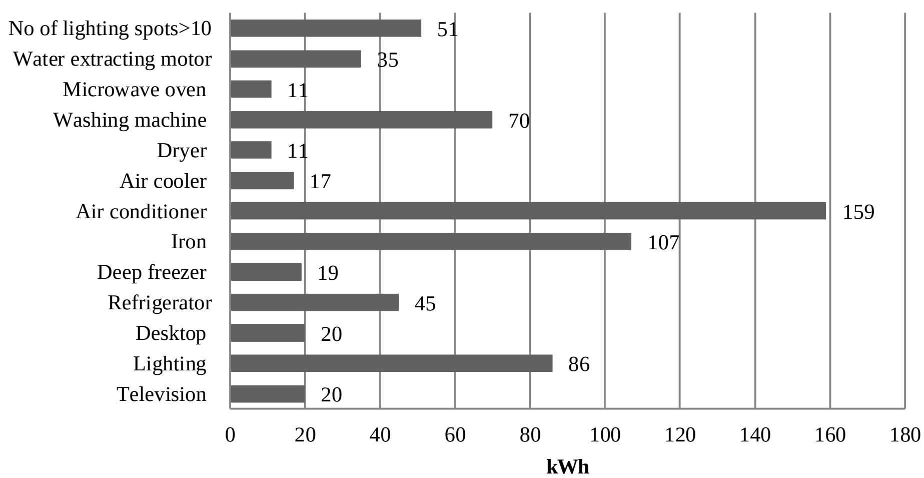


Fig. 4. Mean Electricity Estimates for Different Appliances in kWh for April 2013



3.2. Results of Logistic Model

The results of only those variables, which are statistically significant, are given in Table 6. The log odd ratio or coefficient with negative sign refers to a negative relationship between log odd ratio and likelihood of getting affected by the electricity load shedding. The odds ratio 0.27 for gender of the head of household infers that male-headed households are only 0.27 times the odds of female-headed households to suffer from the electricity crises. A comparative analysis of gender specific capacities to use alternative arrangements during load shedding also supports this finding. About 29 percent female-headed households can use the UPS and only 16 percent can afford generators during electricity load shedding. While 24 percent male-headed households can use generators and 26 percent male heads arrange the UPS during electricity load shedding (see Figure 6). Households who have air-conditioners have odds 1.95 times of the odds of households who do not use air-conditioning. However, the data show that higher income households largely use air-conditioners and these households can arrange alternate provisions during electricity load shedding. The odd of district central implies that households who live in the district central have odds of getting affected by electricity crises twice the odds of households who live in other districts (see Tables 6 and 7). The odds of suffering from electricity crises are 0.22 given household resorts to alternative arrangements during electricity load shedding compared with households with no such provisions. Similarly the odds for a street protest implies that households have odds of 0.46 of getting disposed to electricity crises given they come out on the street and protest compared with households who are passive (see Tables 6 and 9).

Table 6

Estimates of the Determinants of Electricity Crises at Household Level

Variables	Coefficient	Odd Ratios	S/E
Intercept	–2.92		1.39
District (central)	0.71	2.03	0.32
Working age households	0.24	1.27	0.11
Electricity expenditure	–0.63	0.53	0.28
Number of dependents	0.46	1.58	0.18
Damages to electric appliances	1.50	4.48	0.21
Electricity theft	0.53	1.69	0.26
Protest in streets	–0.76	0.46	0.35
Coping strategies	–1.21	0.22	0.34
Energy saving	–0.73	0.48	0.19
Number of household members	1.19	3.28	0.45
Ownership of air-conditioner	0.67	1.95	0.32
Gender	–1.3	0.27	0.19
Log likelihood	–255.66		
LR Chi2(12)	76.29		
Probability >Chi2	0.00		
No. of Obs.	2000		

4. DISCUSSION

We use qualitative research methods such as in-depth interviews from focused groups and household's heads to collect views about problem of load shedding and its impact on their well-being. We use two qualitative variables that are electricity crises affected household (CAH) and worst affected household (WAH), (see Table 2). A binary variable with value 1 implies that representative household has suffered from regular electricity load shedding during March-May 2013. Household is termed electricity crises affected household (CAH). We use qualitative research methods such as in-depth interviews from focused groups and household's heads to collect views about problem of load shedding and its impact on their well-being. We use two qualitative variables that are electricity crises affected household (CAH) and worst affected household (WAH). A binary variable with value 1 implies that representative household has suffered from regular electricity load shedding during March-May 2013. Household is termed electricity crises affected household (CAH). The badly hit districts were the Central and the East and least affected was the South (see Tables 7 and 8). Similarly, distributing data on monthly income[32] across districts showed that about 56 percent of the households in the bottom strata live in the district east and the central. Thus more than half of the population affected by electricity crises in these districts comprises poor households.

Another important finding from the household energy survey is that households were not only electricity crises affected but also endured losses to their electrical appliances. The district wise distribution of the worst affected households and electricity theft in the neighbourhood of the worst affected households are shown in Table 8. The data show that 1340 households or about 67 percent of the households are worst affected. A good majority of the worst affected households live in the Central and the East indicating severity of the electricity load shedding in these two districts (see Table 8). The data on electricity theft in the neighbourhood of worst affected households showed that problem of electricity theft is also rampant in the Central and the East. About 7.20 percent in the Central and 15.43 percent households in the East are involved in electricity theft. The K-Electric also complained that the central and the east districts of Karachi have the highest rate of late electricity payments and electricity theft.[33]

The size of the impact of electricity load shedding also varies by gender of the person, job status and district of residence. Table 9 presents various implications of electricity crises, household's views and household's reaction over prevailing electricity crises. The work impact of load shedding varies by job as the worst affected are private employees which are 42.07 percent following own business 16.29 percent, government 13.60 percent and retirees or unemployed 3.79 percent. The variable "daily tasks" combines responses of the household on three important missed out daily tasks: reaching the office in time, pick and drop of children to and from school and complying with doctor's appointment. The data show that 62.50 percent of households missed all three important tasks at least once during March and May because of electricity load shedding (see Table 9). Only 11.01 percent of households could not do the third task only.

[32]Real expenditure is used as proxy for income of the surveyed household and income deciles were computed.

[33]www.pc.gov.pk

Table 7

Electricity Crises Affected Household by District

Districts	Crises Affected Household	Male Headed (Crises Affected Household)	Female Headed (Crises Affected Household)
Central	31.80	31.40	34.68
East	29.88	29.38	33.58
West	11.65	12.01	8.99
South	8.56	8.71	7.43
Malir	14.81	15.23	11.74
Total	96.70	96.73	96.42

Table 8

The Worst Affected Households from Electricity Crises and Electricity Theft by District

District	Worst Affected Household	Electric Theft in Neighbourhood of Worst Affected
Central	22.45	17.20
East	20.58	15.43
West	8.47	6.60
South	5.49	3.70
Malir	10.20	7.09
Total	67.19	50.03

The data show that 51 percent households experience increases in the expenditure on electricity alternatives that is ups, generator, etc., due to load shedding from the last year[34] (see Table 9). The prolonged load shedding also results in diseases like depression, behaviour disorder and Narcolepsy[35] in the population. Timing of the electricity load shedding badly affect working age men and women as 45.03 percent of working heads find increase in medical payments because of sleeplessness resulting from regular load shedding in the night time (see Table 9). About 60.12 percent of the household members could not do well in their exams—as matric[36] and intermediate exams are held during April and May in Karachi.

The load shedding especially during the night time also contributes to the perpetration of street crimes in Karachi as darkness provides opportunity for criminals to commit crime without exposing their identity. The data show that 55.52 percent of the households strongly agree with this opinion. The study finds that female-headed households are less vocal in reporting electricity theft than male-headed households. About 86.93 percent of the male-headed households find an increase in electricity theft while only 13

[34]Only 20 percent of electricity crises affected households reported expenditure on other alternatives like candles, emergency lights, torches etc.

[35]Severe kind of sleep disorder, see for detail www.webmed.com. Working Households heads were asked to report sleep disorders and their visit to hospital for treatment due to load shedding in past three months, 26 percent of the working households reported severe sleep disorder.

[36]Equivalent to GCE advance level exam.

percent women notice the neighbourhood's involvement in electricity theft. Similarly 88 percent male-headed households and only 12 percent of female-headed households find electricity load shedding as an important influencing factor in their decision to vote in the 2013 general elections. About 31 percent of the households viewed increase in the load shedding by multiple times, 46.60 percent found increase and only 9.25 percent viewed no change over the last five years (see Table 9). About 89 percent of surveyed households hold increase in the electricity prices as a reason for multiplying the problem of load shedding. In their view, more and more poor people have resorted to electricity theft to avoid increasing electricity charges. While 88 percent of the households held past governments responsible for prevailing electricity crises (see Table 9).

Table 9

Implications, Perceptions and Reaction of Electricity Crises Affected Households

Variables	All Households	Male Headed Households	Female Headed Households
Implications			
Work impact	73.13	88.59	11.41
Daily targets	62.50	84.53	15.47
Impact on study	60.12	54.01	8.11
Increase in expenditures on alternatives	51.02	58.52	41.06
Increase in medical expenditure	45.03	47.01	55.99
Participation in ceremonies	77.06	46.06	53.94
Electricity theft by neighbourhood	68.65	86.93	13.07
Street crimes	55.52	86.62	13.38
Voting behaviour in 2013 general elections	77.69	88.11	11.89
Perceptions			
Extent of electricity crises in last five years	89.15	89.43	10.57
Role of the last government	87.83	87.65	12.35
Increase in electricity prices	89.16	78.01	21.99
Electricity crises on Election manifesto, 2013	34.01	31.22	2.85
Reaction			
Passive	78.47	82.16	17.84
Protest in media	13.50	87.82	12.18
Protest in streets	16.63	93.01	6.99

Studies by Pasha (2010) and Asif (2011) also showed that failure by previous governments to react timely to the situation are the main reasons behind persisting electricity crises in Pakistan. The data show that 78 percent of households did not complain against electricity load shedding during survey months, and only 16 percent of households took part in the street protests against the power outages (see Table 9).

4.1. Household's Coping Strategies

Finally, we analyse the Household's capacity in coping with electricity crises (see Table 2). The study finds that about 82 percent of households from upper income deciles use generators and 59 percent resort to the UPS during load shedding. However, about 42.24 percent of households could not afford any alternative supplies during electricity load shedding and therefore bear the brunt of load shedding during March-May 2013 (see Figure 5). The study finds that about 41 percent of male-headed households and 47.36 percent of female-headed households cannot afford any alternate arrangement during electricity load shedding. Only 7 percent female-headed and 8.1 percent male-headed households can use the UPS and generators both during the electricity load shedding (see Figure 6). The data show that about 7.48 percent households can arrange the ups and generators both during electricity load shedding. While a larger proportion or 93 percent households can either use a generator or the ups but not both (see Figure 5).

Fig. 5. Use of Electricity Alternatives during Load Shedding by All Households

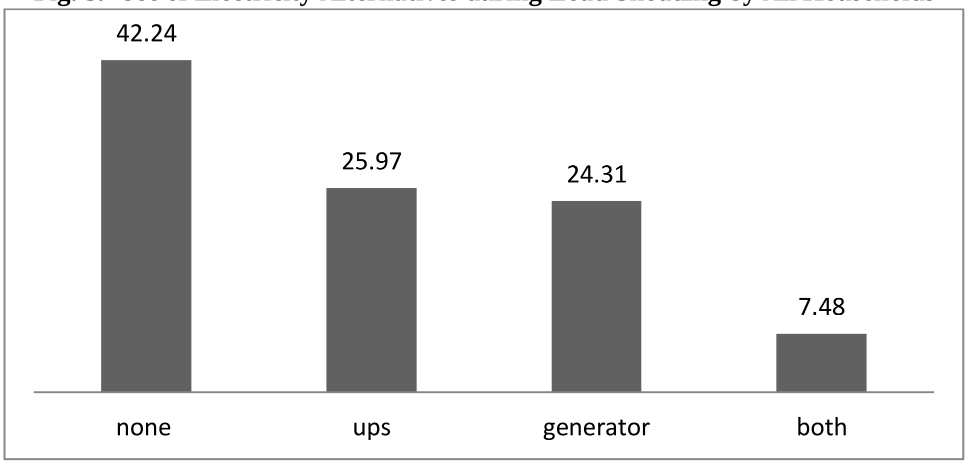
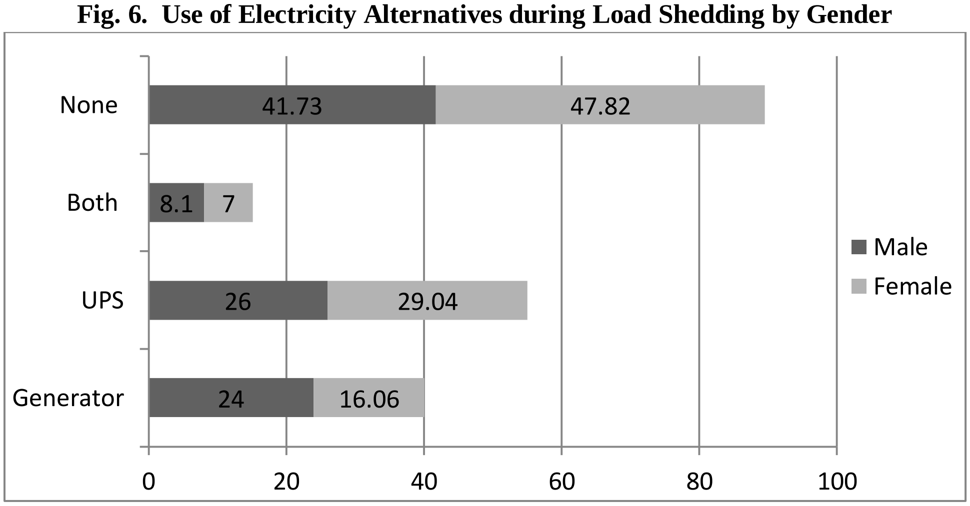


Fig. 6. Use of Electricity Alternatives during Load Shedding by Gender



5. CONCLUSION AND POLICY IMPLICATION

This article analyses the end use based electricity demand and socioeconomic characteristics of households as determinants of prevailing electricity crises in Karachi. The findings of the study suggest that demand for electricity depends on the use of modern electric appliances, and gender specific differences exist in the end uses of electricity consumption. Household's economic and social characteristics interact with end-use electricity consumption. Some effective interactions with end-uses electricity demand are household size, household's income, dwelling type, family unit, gender and marital status of the head of household in Karachi. These variables with electrical appliances also determine the likelihood of suffering from electricity crises for residents of Karachi. Above all, the prevalence of illegal connections, tempering with transmission lines and power theft have compounded the impact of household suffering.

The findings of the conditional demand model (CDM) and logistic model have important theoretical and policy implications. First, analysis of gender specific differences in end-use electricity consumption provides a basis for future research in energy with a gender perspective. Particularly for cities' like Karachi where women comprise majority of the labour force and have sheer dependence on modern appliances. Second findings of logistic model provide useful insight into factors that influence the vulnerability to electricity crises in times of peak demand. Thus, it provides the groundwork for future research in household's vulnerability to electricity failures. Fourth, prospective energy policies in countries like Pakistan should also focus on demand-side-management. Households should be motivated through media campaign; electronic and social media to use all means to conserve energy at the local levels. Fifth, government should encourage investment in the local manufacturing of electricity efficient appliances. Sixth, the most important is the need to legislate law that regards power theft or tampering with electricity meter and transmission lines a criminal offense.

REFERENCES

Ahamad, M. G., and A. K. M. N. Islam (2011) Electricity Consumption and Economic Growth Nexus in Bangladesh: Revisited Evidences. *Energy Policy* 39:10, 6145–6150.

Alam, M., J. Sathaye, and D. Barnes (1998) Urban Household Energy use in India: Efficiency and Policy Implications. *Energy Policy* 26, 885–891.

Ali S., and S. Badar (2010) Dynamics of Circular Debt in Pakistan and its Resolution. *The Lahore Journal of Economics* 15, 61–74.

Ali, M., M. Javed Iqbal, and M. Sharif (2013) Relationship between Extreme Temperature and Electricity Demand in Pakistan. *International Journal of Energy and Environmental Engineering* 4:36, 1–7.

Alter, N. S. H. Syed (2011) An Empirical Analysis of Electricity Demand in Pakistan. *International Journal of Energy Economic Policy* 1:4, 116–139.

Altinay, G. and E. Karagol (2005) Electricity Consumption and Economic Growth: Evidence from Turkey. *Energy Economics* 27, 849–856.

Aqeel, A. and M. S. Butt (2001) The Relationship between Energy Consumption and Economic Growth in Pakistan. *Asia-Pacific Development Journal* 8:2, 101–109.

Asafu-Adjaye, J. (2000) The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries. *Energy Economics* 22, 615–625.

Asif, M. (2011) *Energy Crisis in Pakistan—Origins, Challenges and Sustainable Solutions*. Karachi: Oxford University Press.

Atif, S. M. and M. W. Siddiqi (2012) The Electricity Consumption and Economic Growth nexus in Pakistan: A New Evidence.

Baker, P., R. J. Blundell, and Wright Mickle (1989) Modelling Household Energy Expenditures Using Micro-Data. *The Economic Journal* 99:397, 720–738.

Bartels, R. and D. G. Fiebig (1990) Integrating Direct Metering and Conditional Demand Analysis for Estimating End-Use Loads. *Energy Journal* 11, 79–97.

Bartels, R. and D. G. Fiebig (1998) Metering and Modelling Residential End-Use Electricity Load Curves. *Forecasting* 15:6, 415–426.

Bartels, R. and D. G. Fiebig (2000) Residential End-Use Electricity Demand: Results from a Designed Experiment. *Energy Journal* 21, 51–81.

Bauwens, L., D. G. Fiebig, and M. F. J. Steel (1994) Estimating End-Use Demand: A Bayesian Approach. *Journal of Business and Economic Statistics* 12, 221–231.

Bhattacharyya, S. C. and G. R. Timilsina (2009) Energy Demand Models for Policy Formulation: A Comparative Study of Energy Demand Models. The World Bank, Development Research Group. (Policy Research Working Paper No. 4866).

Branch, R. (1993) Short Run Income Elasticity of Demand for Residential Electricity Using Consumer Expenditure Survey Data. *Energy Journal* 14:4, 111–121.

Burney, N. and A. Naeem (1990) Fuel Demand Elasticities in Pakistan: An Analysis of Household's Expenditure on Fuels Using Micro Data. *The Pakistan Development Review* 29:2, 155–174.

Chaudhry, A. A. (2010) A Panel Data analysis of Electricity Demand in Pakistan. *The Lahore Journal of Economics* 15, 75–106.

Chaudhry, T. (2010) Estimating Residential Electricity Responses in Pakistan's Punjab. *The Lahore Journal of Economics* 15, 107–138.

Chishti, S. (1992) Probability Distribution of Electricity Demand Forecast for the City of Karachi. *The Pakistan Development Review* 31:3, 287–293.

Dalen, M. H. and M. B. Larsen (2013) Residential End-Use Electricity Demand—Development Over Time. Statistics Norway, Research Department. (Discussion Paper No. 736, 1–26).

Dennerlein, R. (1987) Residential Demand for Electrical Appliances and Electricity in the Federal Republic of Germany. *The Energy Journal* 8:1, 69–86.

Dubin, J. A. and D. L. McFadden (1984) An Econometric Analysis of Residential Electric Appliance Holdings and Consumption. *Econometrica* 52:2, 345–362.

Egerlioglu, F., A. Mohammad, and H. Guven (2001) Economic Variables and Electricity Consumption in Northern Cyprus. *Energy* 26, 355–362.

Fartahbaksh, H. U. and A. Fung (1998) A Residential End-Use Energy Consumption Model for Canada. *Energy Resources* 22, 433–443.

Filippini, M. (1995) Electricity Demand by Time of Use—An Application of the Household AIDS Model. *Energy Economics* 17:3, 197–204.

Firth, S., K. Lomas, A. Wright, and R. Wall (2008) Identifying Trends in the Use of Domestic Appliances from Household Electricity Consumption Measurements. *Energy Build* 40, 926–36.

FODP (2010) Integrated Energy Sector Report and Plan. Report Prepared by Friends of Democratic Pakistan (FODP), Energy Sector Task Force, Asian Development Bank and Government of Pakistan.

Haas, R. P., J. Burner, and Auer H. Zoechling (1998) Impacts on Electricity Consumption of Household Appliances in Austria: A Comparison of Time Series and Cross-Section Analyses. *Energy Policy* 26:13, 1031–1040.

Haq, N. U. and K. Hussain (2008) Energy Crisis in Pakistan. Policy Research Institute, Islamabad. (Technical Report).

Haroon, J. and K. A. Jahan (2007) Trends in Regional Human Development Indices. Social Policy and Development Centre, Karachi. (Research Report No. 73).

Hasan, S., A. Imtiaz, M. Subhani and A. Osman (2012) The Energy Short Fall and its After Effects (A Case Study for Karachi City in Context to Karachi Electric Supply Corporation). *Science Series Data Report* 4:2, 42–49.

Heltberg, R. (2005) Factors Determining Household Fuel Choice in Guatemala. *Environment and Development Economics* 10:3, 337–361.

Hosmer, W. David and S. Lemshow (2000) *Applied Logistic Regression*. (2nd Edition), Wiley Series in Probability and Statistics .

Hsiao, C., C. Mountain, and K. H. Illman (1995) A Bayesian Integration of End-Use Metering and Conditional-Demand Analysis. *Journal of Business and Economic Statistics* 13:3, 315–326.

Hussain, M. A., *et al*. (2010) Forecast Models for Urban Extreme Temperatures: Karachi Region as a Case Study. *Nucleus* 47:4, 301–311.

Iqbal, M. (1983) Residential Demand for Electricity and Natural Gas in Pakistan. *The Pakistan Development Review* 22:1, 23–36.

Jamil, F. and E. Ahmad (2011) Income and Price Elasticities of Energy Demand: Aggregate and Sector Wise-analysis. *Energy Policy* 39, 5519–5527.

Jumbe, C. B. L. (2004) Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi. *Energy Economics* 26, 61–68.

Khan, A. M. and A. Qayyum (2007) Dynamic Modelling of Energy and Growth in South Asia. *The Pakistan Development Review* 46, 481–498.

Khan, A., A. Muhammad, and A. Usman (2009) Energy Demand in Pakistan: A Disaggregate Analysis. Munich Personal RePEc Archive (MPRA). (Paper No. 15056).

Kraft, J. and A. Kraft (1978) On the Relationship between Energy and GNP. *Journal of Energy and Development* 3, 401–403.

Lafrance, G. and D. Perron (1994) Evolution of Residential Electricity Demand by End-Use in Quebec 1979-1989: A Conditional Demand Analysis. *Energy Studies Review* 6, 164–173.

Larsen, B. M. and R. Nesbakken (2004) Household Electricity End-Use Consumption: Results from Econometric and Engineering Models. *Energy Economics* 26, 179–200.

Malik, A. (2007) Effectiveness of Regulatory Structure in the Power Sector of Pakistan. (Working Paper No. 25).

Malik, A. (2012) Power Crises in Pakistan: A Crises of Governance. Pakistan Institute of Development Economics, Islamabad. (PIDE Monograph Series).

Merril, Lynch (2007) <www.ml.com/.../2007/ar/pdfs/annual_report_2007_complete.pdf>.

Nasir, M., M. S. Tariq, and A. Arif (2008) Residential Demand for Electricity in Pakistan. *The Pakistan Development Review* 47:4, 457–467.

Pakistan, Government of (2012-13) *Economic Survey 2012-13*. Islamabad: Ministry of Finance.

Pakistan, Government of (2013) The Causes and Impact of Power Sector Circular Debt in Pakistan (Project Funded by USAID).

Parti, M. and C. Parti (1980) The Total and Appliance-specific Conditional Demand for Electricity in the Household Sector. *The Bell Journal of Economics* 11, 309–321.

Pasha, A. G. (2010) *Economic Cost of Power Outages*.

Pasha, H. A., A. Ghaus, and S. Malik (1989) The Economic Cost of Power Outages in the Industrial Sector of Pakistan. *Ecological Economics* 11:4, 301–318.

Pollak, R. A. (1971) Conditional Demand Functions and the Implications of Separable Utility. *Southern Economic Journal* 37:4, 423–33.

Qasim, M. and K. Kotani (2012) Causes of Energy Shortage in Pakistan: An Empirical Evidence. Economic and Management Series, EMS 2013-1. International University of Japan.

Qazi, A., K. Ahmad, and M. Mudassar (2012) Disaggregate Energy Consumption and Industrial Output in Pakistan. (Discussion Paper No. 2012-29).

Quebec (1989) A Conditional Demand Analysis Evolution of Residential Electricity Demand by End-Use. *Energy Studies Review* 6:2, 164–173.

Reiss, P. C. and M. W. White (2005) Household Electricity Demand, Revisited. *Review of Economic Studies* 72:3, 853–883.

Riaz, T. (1984) Energy Consumption and Economic Growth. *The Pakistan Development Review* 23, 431–53.

Sahir, M. H. and A. H. Qureshi (2007) Specific Concerns of Pakistan in the Context of Energy Security Issues and Geopolitics of the Region. *Energy Policy* 35, 2031–2037.

Shahbaz, M. and M. Feridun (2012) Electricity Consumption and Economic Growth: Empirical Evidence from Pakistan. *Quality and Quantity* 46:5, 1583–1589.

Siddiqui, R. (2004) Energy and Economic Growth in Pakistan. *The Pakistan Development Review* 43:2, 175–200.

Siddiqui, R. and R. Haq (1999) Demand for Energy and the Revenue Impact of Changes in Energy Prices. Pakistan Institute of Development Economics, Islamabad. (Research Report No. 174).

Siddiqui, R., *et al*. (2011) The Cost of Un Served Energy: Evidence from Selected Industrial Cities of Pakistan. Pakistan Institute of Development Economics, Islamabad. (Working Papers 2011:75).

Swan, L. G. and V. I. Ugursal (2009) Modelling of End-use Energy Consumption in the Residential Sector: A Review of Modelling Techniques. *Renewable and Sustainable Energy Reviews* 13:8, 1819–1835.

Trimble, C. N. Yoshida and M. Saqib (2011) Rethinking Electricity Tariffs and Subsidies in Pakistan. Policy Note. The World Bank. (WB Report No. 62971).

White, H. (1980) A Heteroscedasticity—Consistent Covariance Matrix Estimator and a Direct Test for Heteroscedasticity. *Econometrcia* 48:4, 817–38.

Wood, G. and M. Newborough (2003) Dynamic Energy-Consumption for Domestic Appliances: Environment, Behaviour and Design. *Energy Build* 5, 821–41.

Xiaohua, W. and F. Zhenmin (2003) Common Factors and Major Characteristics of Household Energy Consumption in Comparatively Well-off Rural China. *Renewable and Sustainable Energy Reviews* 7:6, 545–552.

Yun, G. Y. and K. Steemers (2011) Behavioural, Physical and Socio-Economic Factors in Household Cooling Energy Consumption. *Applied Energy* 88:6, 2191–2200.

Zahid, A. (2012) *Pakistan's Energy Sector: From Crises to Crises—Breaking the Chain*. Pakistan Institute of Development Economics, Islamabad. (PIDE Monograph Series).

Comments

With urbanisation and modernisation of the economy, household electricity demand changes.

The present crisis started in 2006-07 with a gradual widening in the demand and supply gap of electricity. Unfortunately, the growth in demand in this decade was clearly not fully anticipated and sufficient investments were not made to accommodate for this increased demand.

This is a well-researched paper based on households' survey to determine household electricity demand and analyse economic and social characteristics of households as determinants of prevailing electricity crises.

(1) The title of the study portrays the energy consumption pattern of urban households from Sindh, but it gives the impression of metropolitan city of Karachi from Sindh province, i.e., literacy 99 percent, household size 4.5, 99 percent refrigerator and cell phone, 91 percent washing machine, 74 percent have desktop computer and 43 percent AC. This is not the urban profile of Sindh province.

(2) While discussing coping strategy during load shedding, 42 percent households reported no alternative of electricity while the rest is using UPS 24 percent, generator 26 percent and both 7.5 percent. It is observed that these 42 percent households uses candles/ lantern/emergency lights as alternative for lighting purposes i.e. studying, other household chores. It is a big share of HH. The study needs some discussion about it, i.e. Pakistan Panel Households Survey-2010 reported 62 percent use traditional strategies (Emergency lights 22, gas lamps/lanterns 40 percent) while only 2.6 percent used UPS, 2.7 percent generator and 35 percent had no alternative in urban Pakistan.

(3) The study did not highlight one of the reason of high demand/energy crises that is use of air conditioner as 43 percent households owned it and average share of energy consumption is 159 KWh which is 25 percent of total consumption.

The paper is a useful contribution in an important area of present high demand of energy.

Rashida Haq

Pakistan Institute of Development Economics,
Islamabad.