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Determinants of Residential Electricity Expenditure in Pakistan: Urban-Rural Comparison

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Abstract

In this study the authors attempted to find out the determinants of the consumption expenditure on electricity by households. Explanatory variables are income of household, family size, number of rooms in the house, region, province and electricity consuming appliances like AC, fridge, freezer, computer, washing machine and air cooler. The authors found out that expenditure on electricity is income inelastic, increase in family size and number of rooms increases the expenditure on electricity. Households living in urban areas have more expenditure on electricity as compared to the rural households. Households in urban and rural areas of Punjab have more electricity expenditure as compared to the rest of the provinces. The acquisition of electric appliances contributed positively towards the electricity expenditure. A.C. and Freezer are the two most powerful contributors.

Keywords: Households; Electric expenditure; Electric appliances; Pakistan

JEL classification: Q4, Q41, Q43

1. Introduction

At present, Pakistan is facing a power shortage ranging between 4000-5000 megawatts (MW), because supply of electricity is increasing much slowly as compared with its demand. On overage demand for electricity has increased at a rate of 9.5% per annum during last four years due to urbanization, industrialization and electrification of the rural areas.. It is projected to grow by 8.7% per annum.[2]

If we look at sectoral consumption of electricity by economic groups, we find that domestic group is the largest consumer of electricity with average annual share of 45%. In the last four years (2003-04 to 2006-07), on average, consumption in domestic sector has increased by 8.9% annually. Number of electricity consumers in March 2008 was 17.73 million, out of which 15.02 million were the domestic consumers. In 1997-98 domestic consumers were

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[2] Source: Pakistan Economic Survey (PES) 2007-08.

8.4 million. Thus, the number of electricity consumers has doubled within 10 years as shown in table 1.2. If we look at the supply side we find that projected supply is 2000-3000 MW lesser than demand.

Since the supply falls short of the demand and there is continuous increase in the electricity consumption, it is highly desirable to conduct a demand side analysis regarding domestic consumers of electricity, as they constitute the largest group of electricity users (see table and figure, 1.1). Instead of considering the supply side of electricity, the alternative option is to study the demand side approach in electricity through demand management.

Table 1.1: The Share of Consumption of Electricity by End-Users (in %)

Year	Households	Commercial	Industrial	Agriculture
1997-98	42.2	5.2	27.6	15.5
1998-99	44.8	5.5	27.7	12.9
1999-00	46.9	5.5	29	9.9
2000-01	46.9	5.8	29.4	10.1
2001-02	45.8	5.9	29.8	11.1
2002-03	45	6.1	30.8	11.4
2003-04	44.9	6.4	30.3	11.7
2004-05	45	6.7	30.3	11.4
2005-06	45.4	7	29.3	11.7
2006-07	45.8	7.4	29	11.3
Average	**45.27**	**6.15**	**29.32**	**11.7**
July-March				
2006-07	45	7.3	29.7	11.5
2007-08	45.6	7.4	28.4	11.8

Source: Pakistan Economic Survey: 2007-08

For this reason, detailed analysis of consumers' electricity consumption is necessary and is the focal point of this paper. In this paper we intent to find out the determinants of domestic electricity expenditure (per month) using micro-data. This is desirable because a household level study can incorporate household characteristics and shed some light on the nature of consumer responses [See Filippini & Pachauri (2004)]. Moreover, by including different geographical factors we can see consumer behavior in different sub-groups. Thus, use of micro-data provides more detail and depth as compared to the aggregate level study. Unfortunately, all the studies which

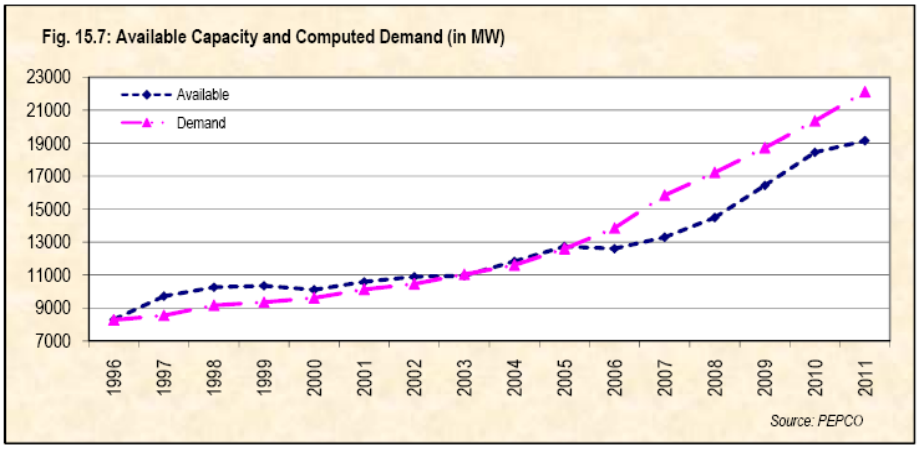
have taken up this topic in Pakistan have used aggregate level data. Therefore there is a need for micro level study on electricity demand in Pakistan using the micro data. Micro-data study is also important because it can suggest something about the demand management policy. A demand management policy could be a better solution, in the short run because changing the supply of electricity will require a longer timeframe. And even after increase in

Table 1.2: Consumers by Economic Groups (Thousands)

Year	Households	Commercial	Industrial	Agriculture	Other	Total
1997-98	8455	1397	187	171	8	10218
1998-99	8912	1517	190	173	8	10800
1999-00	9554	1654	195	175	8	11586
2000-01	10045	1737	196	180	8	12166
2001-02	10483	1803	200	184	8	12678
2002-03	11044	1867	206	192	9	13318
2003-04	11737	1935	210	199	10	14091
2004-05	12490	1983	212	201	10	14896
2005-06	13390	2068	222	220	10	15910
2006-07	14354	2152	233	236	11	16986
July-March						
2006-07	14069	2132	230	233	11	16675
2007-08	15026	2214	240	243	11	17734

Source: PES 2007-08

Figure 1.1: Available Capacity and Computed Demand (in MW)



supply the demand management policy will ensure against a power crisis as is faced by the country today.

2. Brief Literature Review

Understanding the demand and supply forces and their determinants in electricity sector is important because today our lives are directly affected by it as we have become dependent on the use of appliances run by electricity. In the light of current electricity crisis the topic of demand side management has gained special significance. Despite its significance there has been no considerable work regarding electricity demand, on household level data, in Pakistan. Perhaps because the demand for electricity was considered as "given" or predetermined. Whatever the reason may be, the demand side of electricity is still waiting to be explored in Pakistan. We still have to develop insight about the dynamics of electricity demand in our country. In this paper our goal is to see; what are the major determinants of household expenditure on electricity (demand) using household level data.

There are a host of studies that have taken up the topic of electricity demand regarding domestic, industrial and commercial users. Some of the studies focused on residential demand for electricity are mentioned here. Houthakker (1951) has studied domestic demand for electricity in UK using cross sectional data on 42 provincial towns for a period from 1937-1938. He used OLS technique to estimate double log models which included variables like; average annual electricity consumption of each household with a decreasing two part tariff, average income , marginal price of electricity, marginal price of gas, and average holding of electricity consuming appliances per household.

Fisher and Kaysen (1962) have focused on both residential and industrial demand for electricity in US. by using a dataset having observations for 47 states for the period 1946 to 1957. They used OLS and analysis of covariance techniques. The model they estimated was in log form and included ex post average price and per capita income, both of them in real terms. They explicitly differentiated between the short run and long run domestic electricity demand, for the first time.

Houthakker and Taylor (1970) have analyzed the residential demand for electricity using annual time series data on personal consumption expenditure for the period 1947-1964. They used state adjustment model to make an equation for personal consumption expenditure on electricity. They

estimated both short run and long run elasticities. Other studies on US residential demand for electricity include; Wilson (1971), Mount *et al* (1973) and Anderson (1973) among others.

Researchers discussed in detail the issues involved in modeling the demand for electricity including Houthakkar (1962), Fisher & Kaysen (1962), Houthakkar & Taylor (1970), Wilson (1971), Cargil & Meyer (1971), Mount *et al* (1973), Anderson (1973), Anderson (1971), Lyman (1973) and Houthakkar *et al* (1973), Taylor (1975).

Moreover, Reiss and White (2001) have studied US household electricity demand in the short run and have taken care of problems like non-linearity of electricity prices, data aggregation and heterogeneity in household's price sensitivity. They used data of a representative sample of 1307 California households for year 1997. Estimation is done using Generalized Method of Moments (GMM) technique.

Filippini and Pachauri (2004) have studied residential demand for electricity for all urban areas of India. They have used cross section data containing 30,000 households for the year 1993-94. They estimated three demand functions in log form using monthly data for the summer, winter and monsoon seasons. The variables they included were average price of electricity, price of kerosene, price of LPG, total household expenditure, covered area of the house, size of town, size of household and age of head of the household. They did not include the information about the appliance held by the households. Their results show that the residential electricity demand is income and price inelastic in all three seasons whereas geographical, household and demographic variables included, show significant impact on electricity demand.

Other micro-data studies which have taken up this topic are; Halvorsen (1975) for USA, Parti & Parti (1980) for San Diego, Barnes *et al.* (1981) for USA, Murthy (2001) for India and Dubin & McFadden (1984) for USA. Studies which have taken up this topic on the aggregate level and studied it in the time series settings include; Holtedahl and Frederick (2004) for Taiwan, Akmal & Stern (2001) for Australia, Zachariadis & Pashourtidou (2006) for Cyprus, Halicioglu (2007) for Turkey, Dergiades and Lefteris (2008) for USA and Hondroyiannis (2004) for Greece, among others.

In this study our goal is to conduct a detailed analysis regarding the determinants of residential electricity demand in Pakistan by including the

relevant demographic and economic variables. In this respect, we have used cross-section data discussed in detail in section 5.

3. Residential Demand for Electricity in Pakistan

Electricity is a commodity which is not directly consumed by the households. Households get utility from the use of electricity consuming appliances, so the demand for electricity is a derived demand, originating from the demand for services provided by electricity consuming appliances. Use of the appliance may depend on the habits and preferences of the consumers, which are different hence leading to heterogeneity. In our analysis following literature [e.g. Taylor (1975)] we identify short run as a period in which the appliance stock of a household is assumed to be constant, hence the changes in electricity consumption occur due to changes in the utilization rate of the existing appliances. In long run the appliance holding can change[3].

In the short run the residential demand for electricity is mainly determined by the price of electricity and the alternative forms of energy, income of the household, family size, number of rooms in the house, demographic factors like rural or urban area, temperature and seasonal factors and the appliance holding of the household.

In Pakistan we have increasing block pricing, this makes modeling demand difficult, hence in the our analysis we will drop the price variable. In our analysis we will not address the complex issue of multistep block pricing; there are two reasons for it. One is the data about the marginal price faced by the consumers is not readily available. Second is the unit prices faced by consumers are uniform thus, this variable lacks the required variability. In our study we have not included the seasonal variable, because of unavailability of data. Our study is thus prone to specification bias because of unavailability of data.

This paper is arranged as follows: section 4 is about the methodology used. Section 5 focuses on the data sources and sample details. Empirical results are summarized in section 6. Analysis of the results is in section 7. Section 8 gives the conclusion.

[3] Long run analysis is skipped in this paper due to data availability constraint, since we have only cross sectional data for the short run (SR).

4. Methodology

In our analysis we will see how the monthly expenditure by households on electricity is related with a set of given variables, using the OLS technique on cross section data of about 9,500 households. We will estimate the following general form;

$$Q_i = f(Y_i, NF_i, NR_i, DAP_{ik}, DRG_i, DPR_i) \qquad (4.1)$$

Where

Q = consumption expenditure by household on electricity (Rs/month)

Y = monthly income of the household.

NF = Number of family members.

NR = the number of rooms in the house

DR = dummy showing the region. 1 for Urban, and 0 for rural.

DAP = shows the presence of a particular appliances. Appliances selected are freezer (fzr), fridge (frg), air conditioner (ac), air cooler (aclor), washing machine (wm) and computer (comp). Value of each category is 1 for the presence of the particular appliance, and is 0 otherwise.

DPR = dummy showing the province, i.e. Punjab, Sindh, NWFP and Baluchistan. 1 if the household belongs to the specific province, 0 otherwise.

Following literature we estimate equation in double log form, because in that case the coefficients of the variables will provide the respective elasticities and semi-elasticities. We estimate the following equation:

$$\ln Q_i = \alpha_1 + \alpha_2 \ln Y_i + \alpha_3 NF_i + \alpha_4 NR_i + \alpha_5 DR_i + \alpha_6 Dsndh_i + \alpha_7 Dblch_i + \alpha_8 Dnwfp + \alpha_9 Dfrz_i + \alpha_{10} Dfrg_i + \alpha_{11} Dac_i + \alpha_{12} Dacolr_i + \alpha_{13} Dwm + \alpha_{14} Dcomp_i + \mu_i \qquad (4.2)$$

The income elasticity of electricity demand α_2 is expected to be positive, because as the income of the household increases their consumption of electricity also increases by consuming more appliances. The semi-elasticities α_3 and α_4 are expected to be positive, because as the number of family members and rooms in a house increases its electricity consumption is also expected to increase. The coefficients α_5 through α_{14} cannot be interpreted as semi-elasticities. The percentage effects of the dummy variables

on the electricity expenditure can be derived by exponential transformation of the coefficients.

The electricity demand of a household depends on the demographic factors. The households living in urban areas are expected to consume more than those in rural areas. Similarly, there is expected to be province wise differences in electricity consumption, to capture these differences we are using dummy variables for each province by using Punjab as base category.

In the initial analysis we take a large sample which includes both urban and rural households. Then we conduct separate analysis for rural and urban regions to see the difference in response of electricity expenditure to the selected set of explanatory variables. It is expected that there will be strong heterocedasticity in the data because of its cross sectional nature. To counter this problem we took the log of the consumption expenditure of electricity and income. Other problems could be the presence of specification bias because of the missing data about the season in which the households were surveyed.

5. Data

All the data used are taken from Pakistan Social and Living Standard Measurement Survey (PSLM) Round-1 (2004-05). This survey is conducted by the Federal Bureau of Statistics. The survey following Core Welfare Indicators Questionnaire (CWIQ) approach was conducted with the aim to provide data for use by the government in formulating the poverty reduction strategy as well as development plans at district level and rapid assessment of programs.[4]

This is the first time that Federal Bureau of Statistics (FBS) has conducted. The field work was carried out between September, 2004 and March, 2005. Simultaneously FBS conducted Household Integrated Economic Survey (HIES) by contacting more than 12000 households for the purpose of collecting detailed information about the income and consumption expenditure of the households. Hence, we have used the same households. But after accounting for missing values and outliers we were left with 9,238 household observations, which include households from all four provinces and from both rural and urban areas of Pakistan. Use of monthly data reduces the possibility of aggregation bias over time.

[4] A sample survey covering approximately 76,520 households to provide district level indicators in the sectors such as Education, Health, Water Supply & Sanitation and Household Economic Situation & Satisfaction by facilities and services use.

The combined sample (Rural and Urban) has 4,898 households from rural area and 4,340 households from urban areas. Province wise distribution of households included in the combined sample is given in Table 5.1.

Table 5.1: Province wise distribution of households (combined).

Province	No. of Observations.	Percentage
Punjab	4075	44.1
Sindh	2215	23.9
Baluchistan	1151	12.5
NWFP	1797	19.4

The separate sample used for urban area includes 4,409 households' observations. The province wise distribution of households included in this sample is shown in table 5.2.

Table 5.2: Province wise distribution of households (Urban).

Province	No. of Observations.	Percentage
Punjab	1917	43.5
Sindh	1162	26.3
Baluchistan	586	16.8
NWFP	744	13.3

The separate sample used for rural areas include 4,997 household observations. The province wise distribution of households included in the sample is shown in table 5.3.

Table 5.3: Province wise distribution of households (Rural).

Province	No. of Observations.	Percentage
Punjab	2760	44.8
Sindh	1094	21.9
Baluchistan	572	11.4
NWFP	1094	21.9

6. Empirical Results

The results of estimation of equation (4.2) for both the rural and urban combined and separate samples are given in table 6.1 below.

6.1. Analysis

When we are looking at a cross section data of 9,238 households, it is obvious that the appliance holding will be having different from one household to the other. Thus our estimated equation for consumption expenditure on electricity will be encompassing the effects of variations in the utilization rate and also the effect of intra-household change in appliance stock. Keeping this in mind our estimated elasticities suggest something both for short run and long run.[5]

Table 6.1: Estimated results of equation (4.2)

Variable	Coefficients		
	Overall	**Urban**	**Rural**
Ln Y	0.153*	0.167*	0.135*
NF	3.52*	3.25*	3.86*
NR	2.52*	3.76*	1.30***
DR	0.14*		
D_{sndh}	-0.02***	-0.01	-0.02
D_{blch}	-0.22*	-0.29*	-0.14*
D_{nwfp}	-0.23*	-0.25*	-0.22*
D_{frz}	0.42*	0.47*	0.32*
D_{frg}	0.35*	0.31*	0.40*
D_{acolr}	0.06*	0.05***	0.09**
D_{wm}	0.16*	0.14*	0.19*
D_{ac}	0.56*	0.52*	0.84*
D_{comp}	0.20*	0.22*	
C	3.98*	4.03*	4.11*
	$\bar{R}^2 = 0.38$	$\bar{R}^2 = 0.426$	$\bar{R}^2 = 0.211$

Note: *,**,*** represent significance at 1%, 5% and10% respectively.

In case of the combined sample, we see that income elasticity is about 0.15, which means that expenditure on electricity consumption is inelastic to the income of the household. 100% increase in income of the household will on average lead to only 15 % increase in the expenditure on electricity. The coefficient associated with the number of family members give the semi-

[5] See: Thomas (1987)

elasticity. Its value in the case of combined sample is 3.52, which means if on average family size increases by 1 unit i.e. member, the household expenditure on electricity will increase by 3.52%. Similarly, the coefficient associated with the number of rooms in the house, represent semi-elasticity.

Its value is 2.52, which means that a unit increase in number of rooms i.e. one more room, will on average increase the electricity expenditure by 2.52%, this is because of increased expenses on lighting and air circulation.

The rest of the coefficients in our model are the dummy variables, and because our dependent variable is in log form, we cannot interpret the coefficients of these dummy variables as semi-elasticities. To find out the percentage effect of the dummy variables on the dependent variable we have to perform the exponential transformation of the coefficients of these dummy variables. Nevertheless, the sign of the coefficients also explain the effect of the dummy variables. The results show that the electricity expenditure is significantly higher in the urban areas as compared to the rural areas. This is probably because of more chances of electricity theft in rural areas as compared to the urban areas. Another reason could be the greater hours of load shedding in rural areas as compared to the urban areas. Also, there is less trend of using electricity consuming appliances and because of lower income in rural areas the appliance stock the households have is also limited.

Similarly, electricity expenditure is lesser in other provinces as compared to Punjab. The coefficients for Sindh, Baluchistan and NWFP are -0.02, -0.22 and -0.23 respectively. Though we cannot tell about the percentage changes in the electricity expenditure due to change in province but the magnitude of the coefficients is comparable. For example we can see that in Sindh electricity expenditure is slightly lower than Punjab, whereas electricity expenditure of Baluchistan and NWFP is much lower than Punjab. We can also see that the difference in electricity expenditure between Sindh and Punjab is very small, and that too is significant on 10% level significance. The results thus suggest that highest electricity expenditure is in Punjab, then comes Sindh, then Baluchistan and lowest electricity expenditure is in NWFP. This may be because of the non-payments of electricity dues in NWFP which is a common practice in some areas of NWFP and Baluchistan. The expenditure on electricity may also be lower because of more hours of load shedding in those provinces. Also, because these provinces are less developed as compared to Punjab and poverty is higher in those areas, appliance stock of households would be lesser than that of the Punjab.

The dummies for the appliances included in the model show that presence of an appliance always contributes positively towards the electricity expenditure. The highest contributor towards the electricity expenditure is air conditioner, followed by freezer, fridge, computer, washing machine and air cooler, respectively.

If we compare the results of urban and rural areas we find that income elasticity of expenditure is higher in urban areas as compared to the rural areas. The income elasticity is about 0.17 in urban and 0.135 in rural areas. It means a unit increase in the income of household living in urban area will increase their expenditure on electricity consumption by 17% whereas by 13.5% in rural areas. This is because appliance stock is expected to be lesser in rural households and trend of electricity consumption is comparatively lesser in rural areas. So, an increase in income will only lead to increase in the utilization rate of the existing lesser stock of appliances, thus showing lesser income elasticity.

The semi-elasticity associated with the number of household members is 3.25 in urban areas and 3.86 in rural areas. This results is different from expected, and cannot be rationalized. The semi-elasticity associated with the number of rooms in the house is 3.76 in urban areas and 1.30 in rural areas. This result is according to the expectations. In rural areas the construction and the degree of electrification of houses is different than those of the urban areas. In urban areas the lighting and air circulation equipment is more frequent and extensive in the rooms as compared to the rural areas. Thus an increase in the number of rooms in an urban household leads to increase in electricity expenditure of about 3.76% as compared to 1.30% in the rural households.

If we look at the province wise differences we see that in case of urban sub sample the expenditure on electricity is not significantly different in Punjab and Sindh, but is lower in NWFP and much lower in the Baluchistan.

Thus, electricity expenditure is lowest Baluchistan in case of urban sub sample. If we look at the province wise distribution of the household electricity expenditure in the rural areas we find that there is no significant difference in Punjab and Sindh, but electricity expenditure is lower in Baluchistan and lowest in NWFP. Thus, in case of rural sample, NWFP shows the lowest electricity expenditure, even lower than the Baluchistan, this may be due to high electricity theft in rural areas of NWFP or due to lack of electrification or load shedding.

The appliance dummies we included in our model show that the presence of an appliances always contributes positively towards the electricity expenditure. The highest contributor in case of urban sample is AC, after it come freezer, fridge, computer, washing machine and air cooler, respectively. In case of rural areas the sequence of contribution in order of highest to lowest is; AC, fridge, freezer, washing machine and air cooler respectively. Computer was excluded in the case of rural sample because it appeared insignificant, and only less than 1% of rural households had a computer.

7. Conclusions and Policy Implication

In the current study it is attempted to explore the determinants of the consumption expenditure on electricity by households on entire country as well as on urban-rural basis. For this purpose, we have included the variables including income of household, family size, number of rooms in the house, region, province and electricity consuming appliances like air-conditioner (AC), refrigerator, freezer, computer, washing machine and air cooler. It was found that expenditure on electricity is income inelastic, increase in family size and the number of rooms raises the expenditure on electricity on household level. Households living in urban areas have more expenditure on electricity as compared to the rural households. Households in urban and rural areas of Punjab have more electricity expenditure as compared to those in other provinces. Since the presence of electricity-consuming appliances always contributes positively towards the electricity expenditure. The same evidence is empirically proved here. Air-conditioner and Freezer are the two most powerful contributors. Thus, to control or reduce the demand for electricity, use of air conditioner and freezer must be reduced.

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