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# Households' Energy Consumption Pattern and Demand in Pakistan

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**Abstract** *This study examined household energy consumption pattern in Pakistan using Linear Approximate Almost Ideal Demand System (LA-AIDS). Price and expenditure elasticities estimated for the energy demand using a household income and expenditure data of the year 2011-12. The energy consumption expenditure pattern of rural and urban region is different. The study reveals that electricity is the most important and highly consumable source of energy for the household living in the country. Electricity and natural gas are the highly consumed fuel in the urban areas, whereas, electricity and firewood in the rural areas. The energy consumption expenditure is inelastic with respect to changes in income except for firewood for urban region. All the estimated expenditure elasticities of the energy types were found less than one indicating that energy consumption is the necessity for the household.*

**Key Words:**

Household Energy Demand, Elasticities, LA-AIDS, Energy Consumption Pattern, Pakistan

**JEL Classification**:

D11, D12, Q41

## Introduction

One of the major and important prerequisite for a country's growth and development is the access to uninterrupted and affordable energy (Khan et al., 2015). Energy is an indispensable input in both production and consumption processes (Khan & Ahmad, 2008). The race to economic growth, development and ever-increasing population have increased per capita demand of energy. Even the already developed economies like USA, France and Germany have not been only sustaining but also increasing their economic growth through increase in energy consumption (Ahmed et al., 2016).

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The situation in developing countries is very different where more than half of the energy is used for cooking purposes only (Foysal et al., 2012). Foysal et al., (2012) further show that the energy consumption of rural households constitutes over 70 % of the total use of national energy in Asia. These two phenomena highlight the importance of understanding consumption pattern of energy at household level. This understanding helps in comprehending the nexuses between households' income, prices and energy demand which is very important for developing energy production and consumption policies (Madlener et al., 2011). Such knowledge and understanding is more important in Pakistan, one of the emerging economies of the world and member of NEXT-11. The country can only sustain its high economic growth through the supply of cheap energy. Cost of energy is a large part of the cost of production of goods and services and an important determinant of cost of doing business. Cheaper energy can also make the country's exports more competitive in international markets. Hence, the dynamic role of energy cannot be underplayed in Pakistan.

However, presently Pakistan is facing severe energy crisis and this crisis has badly affected the economy of Pakistan (Rashid & Sahir, 2015). During the last decade, annual energy demand grew at 5%. This demand is still expected to grow more as frequent shutdown of electricity is very common in the country. The energy crisis of Pakistan has badly affected the economy of Pakistan. Frequent shutdowns of electricity have created unrest in the form of mental anxiety and its negative effect on economy increased unemployment in the country. Households in the country are consuming nearly 46 % of the electricity as compared to developed countries where this sector consumes about one-fourth of the energy (Rashid & Sahir, 2015). Hence, it is important to understand household energy consumption behavior in Pakistan.

This study uses household data to estimate own and cross price compensated and uncompensated demand and income elasticities for energy in Pakistan. These elasticity estimates provide useful information about sensitivity of consumer to changes in energy prices or income. The elasticities give better understanding of consumer behavior and developing pricing policies for households and other sectors of the economy (Bekhet & Othman, 2011). For example, in case of energy price shock, what level of support and protection to low-income household will be required if government plans to support the vulnerable group. Estimates of elasticities are also important for reforming energy price subsidies practiced in Pakistan and most of the other developing countries (Bacon et al., 2010).

However, earlier studies have ignored economic theory while estimating price and expenditure elasticities. In a more recent study, Khan and Abbas (2016) examine the dynamics of electricity for sectoral and aggregate levels in Pakistan. They estimated the relationship between electricity demand, real income and price of electricity. They ignored cross-price effects, homogeneity and

aggregation conditions while estimating demand for electricity. Mirza et al., (2008) and Filippini and Pachauri (2004) also ignored these properties (i.e. cross-price effects, homogeneity and aggregation) while studying energy demand in Pakistan and India, respectively. Lin et al., (2014), Suguira et al., (2013) Song et al., (2012), and Verma et al., (2011) are some of the other recent studies investigated consumption behavior of energy but ignored economic theory specifically properties of demand function in their analysis. This study considers cross-price effects, homogeneity and aggregation as per requirement of economic theory while studying energy consumption at household level in Pakistan, and this our main contribution. Towards, this end the study uses LA-AIDS model for estimation using Household Integrated Economic Survey data for the period 2011-12. The most recent available estimates of income and price elasticities of energy for households in Pakistan were estimated in 1990 (Burnay & Akhtar, 1990). The study also for the first time uses micro-level household data for the estimation of household energy consumption pattern in Pakistan. Aggregate level data for studying energy consumption are often used. However, using aggregate level data leads to aggregation bias. The study further contributes by estimating price and expenditure elasticities for different energy sources of households from urban and rural areas. These estimates can help in devising different energy strategies and policies for these groups and energy sources.

## Energy Expenditure Pattern in Pakistan

Table 1 and 2 given below, present average monthly energy expenditure and quantity consumed by households in Pakistan. The energy items include firewood, natural gas, electricity and other fuel. The value of the average US$ was Rs. 90 during 2012. A household spends Rs. 1779.8 per month on all energy items in the country. Average expenditure on energy is Rs. 2015.9 in urban areas as compared to Rs. 1605.2 in rural areas. Hence, urban households spend about 25 % more on energy as compared to rural households. Among the energy items, the proportion of expenditure on electricity is high in both areas. However, this proportion is relatively higher in urban areas because of its higher availability. Rural areas face frequent power shutdown that last for hours and as a result a household has less opportunity to spend on elasticity. In urban areas, the expenditure on electricity is followed by natural gas and firewood. On the other hand, in rural areas, the expenditure on electricity is followed by firewood due to non-availability of natural gas in most of the rural areas of the country. The higher demand for fire wood in rural areas puts more pressure on forests and agroforestry in the country.

**Table 1. Monthly Energy Expenditures of Household Across Regions in Pakistan (Rs./Month)**

| Energy Type | Urban | Rural | Pakistan |
|---|---|---|---|
| Firewood | 134.60[a] (6.68) | 521.65[b] (32.49) | 356.40 (20.02) |
| Electricity | 1398.94[a] (69.39) | 657.30[b] (40.94) | 973.32 (54.69) |
| Natural Gas | 448.83[a] (22.26) | 148.25[b] (9.23) | 276.38 (15.53) |
| Other Fuel | 33.49[a] (1.66) | 278.02[b] (17.32) | 173.87 (9.769) |
| **Total Expenditure** | **2015.86** | **1605.22** | **1779.79** |
| **No of Households** | **6730** | **9046** | **15782** |

*Source: Authors own calculation using HIES 2011-12.* The figures in parentheses are budget share of fuel item in percent.

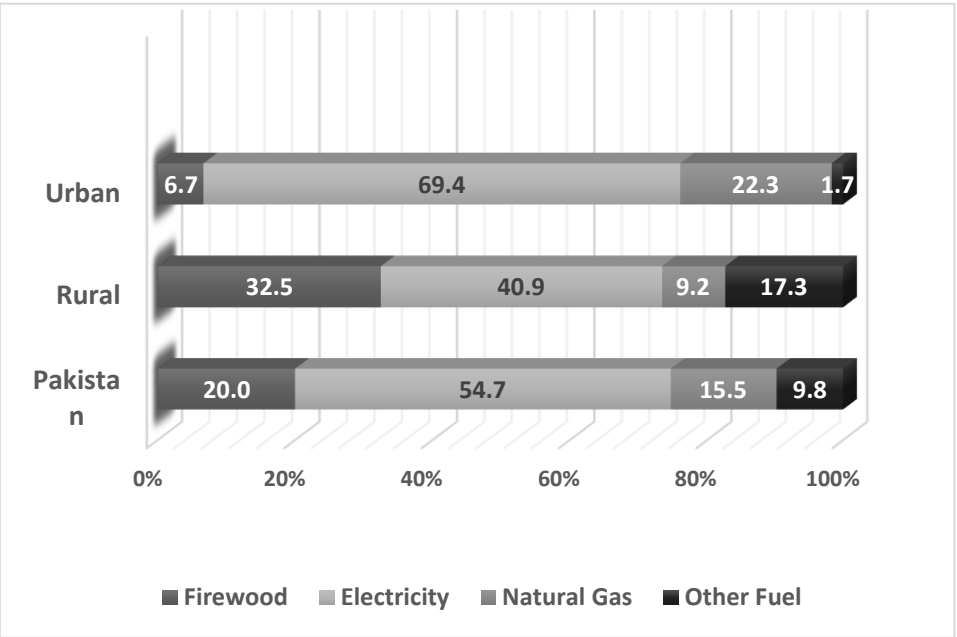
**Table 2. Monthly Average Energy Quantity Consumed by Household in Pakistan**

| Energy type | Urban | Rural | Pakistan |
|---|---|---|---|
| Firewood (Kg) | 18.67[a] | 80.41[b] | 54.06 |
| Electricity (Units) | 187.19[a] | 97.65[b] | 135.80 |
| Natural Gas (MMBtu) | 2.97[a] | 0.97[b] | 1.82 |
| Other Fuel (Kg) | 9.30[a] | 94.69[b] | 58.31 |
| No of Households | 6730 | 9046 | 15782 |

*Source: Authors own calculation using HIES 2011-12.*

The place where household is living is a very important indicator for explaining household energy consumption pattern. Figure 1 summarizes percentage share of energy used by rural and urban households of the country. Urban household budget share for electricity is 69.4 %, 22.3 % for natural gas, 8.7 % for firewood and 1.7 % for other fuel. The proportion of expenditure on electricity is still high in rural areas (40.9 %), followed by fire wood (32.5 %), other fuel (17.3 %) and natural gas (9.2 %).

**Figure 1: Budget Share of Household Energy Consumption.**
***Source: Author's Own Calculation.***




## Methods

LA-AIDS is used for studying demand analysis. AIDS has several advantages over its competitors (such as Translog and the Rotterdam models) such as it exactly satisfies the axioms of choice and simple to estimate. It can also be used to empirically test the conditions of symmetry and homogeneity. Deaton and Muellbaur (1980a,b) specify the following demand equation in budget share for LA-AIDS.

$$\omega_i=\alpha_i+\sum_j y_{ij} \ln p_j+ \beta_i \ln\left(\frac{x}{p}\right) \quad \text{---------- (1)}$$

where $\omega_i$ represents budget share of good $i$, $p_j$ is the price of good $j$, $x$ is the expenditure and $p$ is price index approximated by the Stone's price index.

The following theoretical properties of demand are imposed on equation (1).
Adding Up $\sum_i \alpha_i = 1, \sum_i \beta_i = 0, \sum_i y_i = 0$

Homogeneity: $\sum_j y_{ij} = 0$ ---------- (2)
Symmetry: $y_{ij} = y_{ji}$
The parameters of the estimated model are used to derive elasticities using the following relationships. For the good $i$ with respect to good $j$, the different elasticities are estimated using the following relationships.
Uncompensated Price Elasticity of Demand ($\mathcal{E}ij$): $\mathcal{E}_{ij} = \frac{y_{ij} - \beta_i \omega_i}{\omega_i} - \delta_{ij}$ Compensated Price Elasticity of Demand ($e_{ij}$): $e_{ij} = \frac{y_{ij}}{\omega_i} + \omega_j - \delta_{ij}$ ---------- (3)
Expenditure elasticity ($\eta_i$): $\eta_i = \frac{\beta_i}{\omega_i} + 1$
where $\delta_{ij}$ is kronecker delta which is one for own price and 0 for cross prices.
The final estimated equation included socio-economic and demographic variables (such household size, household head education, household employment status, household head age), the number of electricity and gas appliances, house size and regional dummy. Consider a matrix, *v*, consisting of these variables, then equation-1 can be revised as follows.

$\omega_i = \alpha_i + \sum_j y_{ij} \ln p_j + \beta_i \ln\left(\frac{x}{p}\right) + \gamma v$ ---------- (4)

where *v* is the vector of parameters. The study uses Seemingly Unrelated Regression (SUR) of Zellner (1963) for the estimation of the system of equations of LA-AIDS. The Delta method (STATA, 2005) is used for deriving the statistical significance. Due to singularity of the variance and covariance matrix, one of the equations was dropped from the system. So, the equation of expenditure for other fuel group is dropped and the coefficient for the dropped equation is obtained by using the theoretical restrictions imposed on the process of the estimation.

## Data

The study used Household Integrated Income and Expenditure Survey (HIES) of 2012in the analysis. It covers 15,807 households in 2012 (GoP, 2013). The survey used two stages stratified random sample design for selection of a household. The HIES survey collects thorough information on the value and quantities of consumption of different sources of energy. The HIES collects data on patterns of consumption, income of the household by source, characteristics of household and social indicators. This detailed information enables us to study the budget share of different fuel items to estimate the LA-AIDS system.

**Table 3. Description and Descriptive Statistics of Variables**

| Variable | Variable Definitions | Mean | Std.Dev |
|---|---|---|---|
| Firewood Price | Price in Kgs | 4.492 | 63.881 |
| Electricity Price | Price in units | 6.112 | 1.802 |
| Natural Gas Price | Price in MMBtu | 66.902 | 70.009 |
| Other Fuel Price | Price in Kgs | 5.679 | 19.508 |
| Household Head Size | Number of persons in the household | 6.741 | 3.290 |
| Household Head Education | Household head education in years | 5.170 | 5.193 |
| Household Head Employment | 1 if the household head is government official or professional; 0 otherwise | 0.106 | 0.308 |
| Household Head Age | Age of household head in years | 46.336 | 13.596 |
| House Size | Number of living rooms and bedrooms | 2.394 | 1.415 |
| Regional Dummy | 1 if household located in an urban region, 0 otherwise | 0.427 | 0.495 |
| Electricity Luxury Appliances | Number of luxury electricity appliances in household | 1.684 | 1.660 |
| Gas Appliances | Number of gas appliances using by household | 0.671 | 0.959 |
| Total Income | Household total monthly income | 19077.93 | 25975.6 |
| Fuel Expenditure | Household monthly fuel expenditure | 1780.234 | 1682.762 |
| **Total Expenditure** | Household total monthly expenditure | 18884.16 | 20722.64 |

*Source: Computed from the HIES data 2011-12.*

Definition and descriptive statistics of variables used in the analysis are given above in table 3. The table shows that households spend Rs. 1780.2

per month on fuel expenditure in the country with a standard deviation of 1682.8. The average price of electricity is Rs. 6.1 per unit while the price of natural gas is Rs. 66.3 per MMBtu. A household's average size is 6 individuals including four adults and the remaining children. Household's head average age is 46 years. Of the total households, 57.4 % live in rural areas and the remaining in urban areas. House size is measured in terms of number of living (bedrooms). A house consists of about two living rooms. Monthly household mean income is Rs. 19,077 while total monthly expenditure is Rs. 18,884. Household spend about 9.3 % of their income on fuel expenditure.

## Results and Discussion

The SUR estimates of the energy demand system are given in table 4.

**Table 4. Parameters Estimates of the LA-AIDS Model**

| Explanatory Variables | Firewood | Electricity | Natural Gas | Other Fuel |
|---|---|---|---|---|
| Log of Price of firewood | 0.133 (0.009)* | -0.128 (0.009)* | -0.000 (0.002) | -0.135 (0.006)* |
| Log of Price of Electricity | -0.175 (0.017)* | -0.174 (0.017)* | -0.005 (0.004) | -0.035 (0.012)* |
| Log of Price of Gas | -0.053 (0.004)* | -0.045 (0.004)* | 0.047 (0.001)* | -0.065 (0.003)* |
| Log of Price of Other Fuel | -0.035 (0.009)* | -0.028 (0.009)* | -0.001 (0.002) | 0.025 (0.006)* |
| Household Size | 0.006 (0.002)** | 0.007 (0.002)* | 0.008 (0.000)* | -0.006 (0.002)* |
| Household Head Education | 0.017 (0.002)* | 0.022 (0.002)* | 0.000 (0.000) | 0.008 (0.001)* |
| Household Head Employment | 0.125 (0 .026)* | 0.067 (0.027)** | -0.006 (0.006) | 0.069 (0.019) * |
| Household Head Age | 0.001 (0.000)** | 0.003 (0.000)* | 0.000 (0.000) | 0.001 (0.000) |
| House Size | 0.009 (0.006) | -0.017 (0.007)* | 0.001 (0.001) | -0.012 (0.005)* |
| Regional Dummy | 0.112 (0.019)* | 0.096 (0.019)* | -0.033 (0.005)* | -0.047 (0.014) * |

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| | | | | |
|---|---|---|---|---|
| Electricity Appliances | -0.026 (0.006)* | 0.025 (0.006)* | -0.007 (0.001)* | 0.009 (0.005)** |
| Gas Appliances | 0.035 (0.011)* | -0.032 (0.011)* | 0.000 (0.003) | -0.018 (0.008)** |
| Constant | 1.150 (0.043)* | 1.009 (0.045)* | 0.035 (0.011)* | 0.926 (0.032)* |
| Number of Observations | 15782 | 15782 | 15782 | 15782 |
| R-Squared | 0.465 | 0.541 | 0.284 | 0.356 |
| Chi | 13731.91* | 18657.11* | 6263.84* | 8711.73 * |

*Source: own estimation with survey data. Standard errors are reported in parenthesis. *, **, *** Show estimates are statistically significant at 1, 5 and 10% respectively*.

Majority of the estimated parameters included in the system are statistically significant. The coefficient of determination ranges from 0.284 for natural gas to 0.541 for electricity which are not uncommonly low for cross-sectional data. Parameters of SUR regression are not directly interpretable but their significance and sign show their importance and the direction of effect. Results show that out of 16 parameters of own-price, 13 are statistically significant and negative. The increase in household size statistically significantly increases expenditure on all kinds of energy. Similarly, household head's education has positive effect on energy demand except natural gas. House size is statistically significant determinant of the expenditure on electricity and other fuel. Both electricity and gas appliances statistically significantly determine energy demand. Elasticities of these variables show their proportionate effect on energy expenditure and can be easily and meaningfully interpreted.

The study estimates all elasticities of demand for energy. The Marshallian own price elasticity refers to a percentage change in quantity demand of an energy type with respect to a percentage change in price of that energy while Hicksian own price elasticity shows the same effect keeping utility constant. Cross price elasticity refers to the proportionate change in quantity demand of an energy type due to a proportionate change in the price of another energy type. If cross price elasticity for the two sources is positive, then these are said to be substitutes, otherwise these are considered complementary. Cross price elasticity analysis is very useful in determining the nature of complementarity and substitutability among energy types. Expenditure elasticity shows the proportionate change in energy demand due to a percent change in expenditure.

All the estimated uncompensated and compensated own-price elasticities are statistically significant and have the expected negative sign, elucidating that price

of a good has negative effect on its quantity demand. It also shows that the analysis produced theoretically consistent results. These results reveal that the demand for all energy types in both urban and rural areas is price inelastic. Ngui et al. (2011) also show that household energy demand for electricity; fuel wood and charcoal were price inelastic. Gebreegziabher (2010) in addition to charcoal and firewood also found price inelastic energy preferences for kerosene oil. Athukorala and Wilson (2010) also found price inelastic demand for electricity. The estimated Hicksian elasticities are less than the estimated Marshallian elasticities. The Marshallian and Hicksian estimated cross price elasticities for urban and rural areas and Pakistan are presented in Tables 5 and 7, respectively. Most of the Marshallian cross price elasticities are negative indicating that these fuels items are complements of each other. The rest of the cross-price elasticities are positive indicating that fuel types are substitutes for each other.

The expenditure elasticities computed for the rural and urban households are reported in Table 6. The estimated expenditure elasticities for all the fuel types are positive and significant at the 99 % level of significance, indicating that all the fuel types are normal. The expenditure elasticities of firewood, electricity, natural gas and other fuels falls in the range of 0.334 to 0.827.

**Table 5. Uncompensated Own-Price and Cross-Price Elasticities of Demand for Pakistan**

| Energy type | Firewood | Electricity | Natural Gas | Other Fuel |
|---|---|---|---|---|
| **Pakistan** | | | | |
| Firewood | **-0.259** | -0.625 | -0.085 | -0.004 |
| Electricity | -0.139 | **-0.368** | 0.073 | 0.115 |
| Natural Gas | 0.014 | -0.036 | **-0.478** | 0.003 |
| Other Fuel | -1.005 | -0.197 | -0.435 | **-0.706** |
| **Urban** | | | | |
| Firewood | **-0.036** | -0.498 | -0.397 | 0.337 |
| Electricity | -0.088 | **-0.309** | 0.071 | 0.052 |
| Natural Gas | 0.063 | -0.392 | **-0.638** | 0.022 |
| Other Fuel | -0.727 | -0.560 | -0.566 | **-0.159** |

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| **Rural** | | | | |
|---|---|---|---|---|
| Firewood | **-0.421** | -0.340 | 0.002 | 0.050 |
| Electricity | -0.148 | **-0.392** | 0.059 | 0.121 |
| Natural Gas | -0.060 | -0 .077 | **-0.214** | -0.033 |
| Other Fuel | -0.363 | -0.006 | -0.053 | **-0.936** |

*Source: Own estimation with survey data.*

**Table 6. Expenditure Elasticities for Urban, Rural and all Households**

| | **Firewood** | **Electricity** | **Natural Gas** | **Other Fuel** |
|---|---|---|---|---|
| **Pakistan** | 0.334<br>(0.006)* | 0.523<br>(0.003)* | 0.824<br>(0.004)* | 0.275<br>(0.008)* |
| **Urban** | 0.370<br>(0.017)* | 0.674<br>(0.004)* | 0.663<br>(0.005)* | 0.817<br>(0.009)* |
| **Rural** | 0.493<br>(0.005)* | 0.469<br>(0.005)* | 0.827<br>(0.006)* | 0.630<br>(0.005)* |

*Source: Authors own calculation using HIES 2011-12. Figures in parentheses are standard errors. * Shows that estimates are statistically significant at 1% level.*

**Table 7. Compensated Own-price and Cross-Price Elasticities of Demand for Pakistan**

| Energy Type | Firewood | Electricity | Natural Gas | Other Fuel |
|---|---|---|---|---|
| **Pakistan** | | | | |
| Firewood | **-0.184** | -0.382 | -0.143 | -0.031 |
| Electricity | -0.101 | **-0.162** | -0.021 | 0.052 |
| Natural Gas | 0.223 | 0.341 | **0.402** | 0.110 |
| Other Fuel | -0.868 | 0.106 | -0.401 | **-0.672** |
| **Urban** | | | | |
| Firewood | **-0.034** | -0.123 | - 0.308 | 0.327 |
| Electricity | - 0.149 | **-0.595** | 0.070 | -0.046 |
| Natural Gas | 0.093 | -0.015 | **-0.547** | 0.015 |
| Other Fuel | -0.658 | -0.144 | -0.535 | **-0.127** |
| **Rural** | | | | |
| Firewood | **-0.255** | -0.140 | - 0.109 | 0.169 |
| Electricity | -0.008 | **-0.218** | -0.077 | 0.213 |
| Natural Gas | 0.267 | 0.283 | **-0.164** | 0.246 |
| Other Fuel | -0.132 | 0.258 | 0.129 | **-0.754** |

*Source: Authors estimates using HIES 2011-12*

## Conclusions

The study has examined energy consumption pattern of households in Pakistan using a household income and expenditure data. Price and expenditure elasticities

are estimated to examine the energy demand of households living in the rural and urban regions of the country using LA-AIDS. This research applied demand system to estimate energy elasticities. This is a very unique contribution of this research as in the past system of demand is not used to understand energy demand. The pattern of the expenditure of the urban households is quite different from the rural households. The rural households proportionately spend more on the energy consumption. Energy consumption demand is mostly price inelastic with respect to changes in income. The estimated expenditure elasticities of all the energy groups are less than one indicating that all the energy fuel types are necessities for households living in urban and rural regions of Pakistan. Hence, an increase in per capita income of the country will not increase the demand for energy in the country. The increase in demand is mainly stemming from increase in population. There is also a need to reform energy prices and encourage the consumers to shift and adopt modern technology, as a result it will decrease the cost of energy consumption, improving living standard of the people.

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