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An Investigation into Fuel Demand Elasticities and Economies of Scale in Pakistan

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The study aims to investigate the consumption behavior of households towards energy items and impact of socio-economic determinants on fuel demand in Pakistan. To figure out consumer's approachability, subject to different fuel prices and expenditure, demand elasticities are calculated by using Household Integrated Economic Survey data for the year 2015-16. The study also explores the impact of some of the crucial determinants in energy demand modeling and existence of economies of scale. Different determinants including number of earners in a household and number of rooms in a dwelling, number of durable commodities owned by a household and construction type of the house, came out to have a significant impact in determining fuel budget share of households. As the results for housing factors showed that with growing incomes and living standards, energy consumptions is going to further increase Electricity and gas are substitutes of each other and also act separately as substitute or complement of other fuels at national levels. Since all the fuels came out to be necessities, any taxation policy to reduce demand would increase the payment burden on consumers. Finally, scale economies have found in these inelastic fuel items, and they do significantly vary directly or indirectly with changes in their important determinants .

Keywords: fuel demand elasticities; economies of scale; HIES data
JEL classification: Q41; D12; R49

Today microeconomic outlook of energy consumption and expenditure has become the world's most vital and dynamic aspect of economic growth and development. Fuel is essentially required to power different production processes, so its consumption is considered as lifeline for functioning of every sector in any economy. It plays an important role in determining and improving

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Contribution of Authors:

1. The first author has envisaged the initial idea, provided theoretical framework, formulated objectives & research question, crafted policy recommendations and finalized the first draft.
2. The second author has devised methodology, analyzed the data, and infer the results.
3. The third author has reviewed the literature, collected the data, constructed variables, and incorporated the suggested revisions to finalize the draft.

the development status of a country. Thus, use of energy is acknowledged to be an influent part of household budget in private consumption analysis. With its direct and indirect use, fuel consumption is contributing in the life of masses with both positive and negative effects (Dey *et al*., 2004). Economic growth and fuel consumption have mostly proved to depend upon each other in a bidirectional way due to highly energy intensive production processes (Burney & Akhtar, 1990). Hutton (1984) pointed to the fact that to establish a link between fuel payments of households and their incomes, effects of relative prices, incomes and demographic factors in determining domestic fuel consumption should be accounted for. Further, Iqbal (1983), Misra *et al*., (1995), Alabe (1996) showed that future energy demand in domestic sector is going to increase depending upon its positive relationship with income levels and access to fuel sources.

Pachauri (2004), Cohen *et al*., (2005), Kakwani and Son (2005) presented total and per capita consumption expenditures on energy as a whole category or as a certain source constitute a greater part of household budgets. At micro or macro levels, Nesbakken (1998), Dzioubinski and Chipman (1999), Marufu *et al*., (1999), Sahakian (2011) showed that fuel expenditure does respond significantly to total consumption expenditures, prices, climate, location of the residence, availability of fuel source, housing facilities, extent of mechanization, type of fuel use and various other demographic characteristics of households. Jamil and Ahmad (2011) highlighted that fuel demand mostly varies with the changing seasons, availability of different fuel sources, incomes of households, prices of fuels, housing characteristics, household's personal features and so on. In Pakistan, mostly energy mix is observed in fuel use and energy is considered as public commodity. In this way, Burney and Akhtar (1990) found out that domestically used fuels in Pakistan were necessities, had low marginal propensity to consume and were price inelastic too. Basically, fuels were gross complements. From welfare point of view, fuel poverty is clearly observed phenomenon, even in Pakistan (Todd & Steele, 2006; Chaudhry, 2010). It also increases with more number of people falling below poverty line and so tends to use inefficient traditional fuels (Bacon *et al*., 2009). Achieving fuel efficiency and use of environment friendly products could reduce the possible negative effects of increasing energy use (Jan *et al*., 2012; Khudadad *et al*., 2013). Campbell (2018) pointed out that the objective to improve energy use efficiency and reduce the likelihood of its disruption can be obtained through demand side policies. The study concluded that consumers are most responsive to price changes, with long-run price elasticities of demand. Omer (2018) highlighted that fuel demands are generally (own and cross price) inelastic in the short run, but are relatively elastic in the long run.

Over the time, per capita energy consumption has increased worldwide with rising incomes and greater use of consumer goods. Therefore, developed, developing and even underdeveloped countries are trying hard to devise different ways of providing cheap yet efficient sources of energy to facilitate their economic growth. Besides all these efforts, oil, electricity and natural gas comprised of approximately 72.2% of total global fuel demand in 2015 mainly by Industrialized OECD countries, China and Asia.[1]

Pakistan, a developing economy, is striving hard to sustain its growth conditions. With high growth rate of population, differentiated social classes and increasing number of energy consumers every year, it is crucial for the authorities to keep energy demand and supply in balance to facilitate

[1] For further details, see, Key World Energy Statistics Report, 2017.

maximum number of masses. Otherwise, constraints are going to intensify manifold (Pakistan, 2017). In Pakistan, electricity, gas and firewood expenditure shares comprise of the major part of households fuel expenditures. Rich mostly use electricity and poor households use traditional as well as cheap fuel items (Pakistan, 2016). Yet, natural gas and electricity remained two highly subsidized fuel sources in the country.

Keeping this in mind, household fuel consumption trends in Pakistan are studied by using disaggregated fuel sources. Hössinger, *et al.,* (2017) highlighted that estimations of fuel price elasticities are considered a reliable method to predict behavioral demand responses. Labandeira, *et al.,* (2017) stressed that price elasticities of energy demand have become increasingly relevant in estimating the socio-economic and environmental effects of energy policies or other events that influence the price of energy goods. Thus the current study primarily provides detailed demand elasticities and economies of scale phenomenon for disaggregated residential fuel consumption at national level by employing micro level data source of HIES (2015-16). Furthermore, some of the essential household and housing factors have been employed to find out their possible impact on fuel demand.

Method

Economic theory does not provide accurate functional form for econometric modeling. Still, all the empirical work done used modeling derived from two basic approaches of applied microeconomics. First approach utilizes Classical economics of optimization, i.e. the concepts of utility maximization and cost minimization. Models for such demand systems include classical quantity demand equations, linear expenditure systems, budget share demand systems, Translog model and AIDS model. Another approach that do not consider algebraic specification problem, is more mathematical and flexible in nature. Such approach includes Rotterdam model.[2]

To use any functional model, it must satisfy the four criteria of additivity, homogeneity, non-negativity and symmetry. These conditions are derived from the demand theory. Moreover, to choose any functional form satisfying such conditions is a matter of caution and great interest for the analysis of consumer behavior. The present study is more inclined towards using first approach as it regards the application of linear AIDS model based on linear Engel curves.[3]

Deaton and Muellbauer (1980) presented Almost Ideal Demand System (AIDS), which allows exact non-linear aggregation in demand systems. Sulghum (2006) and Xiao *et al*., (2007) provides four main advantages of AIDS model: (i) it is an arbitrary first order approximation to any demand system; (ii) it fulfills the assumptions of consumer choice theory; (iii) it aggregates over consumers; and (iv) this system of demand equations is flexible in nature and easy to interpret. Generally, AIDS model is specified as:

$$w_i = \alpha_i + \sum_j \beta_{ij} \ln P_j + c_i \ln(Y / P^*) + u_i \qquad \text{(A)}$$

[2] An inclusive description of these approaches can be analyzed in studies like Aziz (2009); Aziz & Malik (2010); Sulgham (2006); and Theil (1987).

[3] For complete implications and specifications Engel laws, consult Ahmad *et al*. (2012); Burney and Akhtar (1990), Chai and Moneta, (2010); and Selim (1995).

Here, w_i is the budget share of a certain i^{th} good, α_i is the intercept of i^{th} share equation, θ_{ij} is the slope coefficient of j^{th} good for i^{th} share equation, P_j is the price of j^{th} good and Y is the total consumption expenditure. In order to minimize multicollinearity and avoid non-linearity, AIDS model is approximated by P* which is the Stone Price Index. Here, $\ln P^* = \sum_{i=1}^{n} w_i \ln p_i$. And, with this AIDS model becomes LAIDs models. Finally, the restrictions are: (i) Adding up, $\sum_{i=1}^{n} \alpha_i = 1, \sum_{i=1}^{n} C_i = 0, \sum_{i=1}^{n} \beta_{ij} = 0$; (ii) Homogeneity, $\sum_{j=1}^{n} \beta_{ij} = 0$; and (iii) Symmetry, $\theta_{ij} = \theta_{ji}$.

The adding-up restriction implies that the sum of the estimated expenditures on different commodities must be equal to the actual total expenditure on all the commodities. Further, the stated data set has been used for three fuel items namely (electricity, gas and other energy sources) and an equation for other goods (which includes the shares in all other consumption). The homogeneity and symmetry restrictions have been imposed in terms of model parameters. Since the shares add up to one, only three out of four equations are independent. Therefore, the equation for others has been deled to ensure the non-singularity of the error co-variance matrix. The estimated parameters are invariant to the deleted equation since the iterative Zellner efficient method has been employed and the parameters of the deleted equation[4] are recovered using the restrictions for homogeneity and symmetry.

Economies of Scale: Many social scientists have most of the time observed that poor families try to live in extended families and mutually share their resources to increase their living standard and cope their limited means. Thus, they achieve economies of scale, as an additional member would certainly require less of the resources than being an individual. This provides an opportunity to the larger families to be better off at even low per capita resources, especially when the member households share public goods like shelter, utilities, etc. The gained increase in resources is then utilized to achieve possibly higher level of per capita consumption and welfare of the household in terms of purchasing some more amounts of both private and public commodities. It is also true that larger households sometimes receive quantity discounts because they buy in bulk.[5] The estimated coefficient for household size would be a combination of two effects, specific and income effect. Specific effect is related to the increase in need for the different goods due to the increase in size of household. However, this increase in needs is surely less in proportion than the increase in size due to the presence of scale economies in the large families. Likewise, if the increase in household size causes the household to be poorer in per capita terms, the negative income effect results. Hence, positive sign of the estimate shows specific effect in consumption of increased desires, while a negative sign of the estimate is attributed to the prominence of income effect (Shamim & Ahmad, 2007; Ahmad *et al*., 2012).

[4] The results of deleted equation, which includes the shares in all other consumption, are not reported in the result section.

[5] See for instance, Parpiev & Yusupov (2011); Perali (2001); and Deaton & Paxson (1998).

Variable Description and Data

In regard with the objectives and considered population of the study, i.e. households of Pakistan, Household Integrated Economic Survey (HIES) is selected for the year of 2015-16. The total sample includes 24238 households out of which 8033 (33%) belongs to rural areas and 16155 (67%) belongs to urban regions.

Notably, HIES does not provide information related to prices as they are assumed to remain same across cross-sectional units. Therefore, prices data for electricity and gas, available in different months of period 2015-16, is sourced from Energy Statistical Appendix of Pakistan Economic Survey (Pakistan, 2017), while that of kerosene oil and firewood is retrieved from table of average retail prices of basic articles in PBS's Yearbook (Pakistan, 2016). Household's expenditures are taken in Pakistani Rupees (Rs.). Residential consumption of electricity, gas, other energy resources (including firewood and kerosene oil) are taken in Kwh, Mcft, Kg and Litre, respectively.

Other variables include monthly total consumption expenditure by a given household (MTCE); monthly fuel expenditure by a household on considered fuel commodities (MFE); expenditure or budget share of electricity (WE)/ gas (WG)/ other fuels (WOF); consumed quantities of electricity (QE)/ gas (QG)/ other fuels (QOF) by a household; prices of electricity (PE)/ gas (PG)/ other fuels (POF); household size (HS); total earners in a household (NOE); dwelling size (NR); ownership of durable commodities (NDC); and construction type of a house (CTH).

Results

The semi-log specification of Linearized Almost Ideal Demand System (LAIDS) model to be estimated is as follows. Here, dependent variables are expenditure shares of electricity, gas and other fuels.

$$Y_i = \alpha_0 + \beta_{i1}\ln(X_1) + \beta_{i2}\ln(X_2) + \beta_{i3}\ln(X_3) + c_i\ln(X_4) + \gamma_1 X_5 + \gamma_2 X_6 + \gamma_3 X_7 + \gamma_4 X_8 + \gamma_5 D_1 + \varepsilon_i \quad \text{(B)}$$

Where, Yi is dependent variable showing expenditure share (wi) of electricity (j=1), gas (j=2) and other fuels (j=3), measured in Pakistani Rupees. X1, X2, X3, X4, X5, X6, X7, X8 and D1 symbolize the nine main independent variables i.e. PE, PG, POF, total consumption expenditure scaled by Stone Price Index, HS, NR, NOE, NDC and dummy variable introduced in a model for CTH(D1= 1 for 'Pucca house' and D1 =0, otherwise), respectively. Hence, numerical results obtained are analyzed as follows.

Economies of Scale: Table 1 indicates the estimates for expenditure share on three fuel sources with respect to changes in household size (HS) variable. It is clearly demonstrated in the table that for electricity share equation, the sign for HS is significantly negative for overall Pakistan. It implies that *ceteris paribas*, an additional household member will reduce the expenditure share of electricity due to presence of household level economies of scale in consumption of this fuel item. Thus, electricity has evolved as a public good, which is shared by household members. For gas share equation, positive but significant estimates with respect to HS are gained. So, gas has evolved as a private good in Pakistan. In this case, still it exhibits economies of scale due to specific or necessity effect creating less than proportionate increases in expenditures share of gas.[6] It will be shown later

[6] As mentioned by Ahmad *et al*. (2012) that for necessities specific effect dominates and creates economies of scale in consumption of such consumer goods.

that gas has come out to be a necessity good. Similarly, other fuels category also depicts similar patterns with insurance that in Pakistan this traditional fuel source is a public good. Thus, it also exhibits economies of scale.

Table 1

Demographic and Housing Attributes with respect to Fuel Budget Shares

Variables	Electricity		Gas		Other fuels	
	Coefficient	**t-Stat**	**Coefficient**	**t-Stat**	**Coefficient**	**t-Stat**
Intercept	0.064 (0.000)	13.7126 (0.0047)	0.0182 (0.000)	10.5643 (0.0017)	0.0247 (0.000)	9.9508 (0.0025)
Household size	-0.001 (0.000)	-17.203 (0.0001)	0.0001 (0.066)	1.8421 (0.000)	-0.0001 (0.470)	-0.7221 (0.0001)
Number of rooms	0.00003 (0.855)	0.1824 (0.0002)	0.0004 (0.000)	4.4167 (0.0001)	0.001 (0.000)	6.3500 (0.0002)
Number of earners	0.0001 (0.688)	0.4019 (0.00013)	-0.0001 (0.204)	-1.2702 (0.0001)	-0.002 (0.000)	-11.6357 (0.0002)
Number of durable goods	-0.0013 (0.000)	-20.315 (0.0001)	-0.0003 (0.000)	-10.172 (0.000)	-0.0002 (0.000)	-5.5750 (0.000)
Dummy of construction type of house	0.0013 (0.028)	2.201 (0.0006)	0.001 (0.0313)	2.1531 (0.0003)	-0.0034 (0.0005)	-3.51187 (0.001)
R^2	0.6449	-	0.5009	-	0.5106	-
D-W Stat	1.5469	-	1.4987	-	1.2463	-
F-Stat	3295.118 (0.00000)	-	1821.142 (0.0000)	-	1893.52 (0.000)	-

** P values for coefficient estimates (tested at minimum significance level of 10%) and F-Statistics are in parentheses.*

*** S.E for t-Statistics is in parenthesis.*

Number of Earners in a Family: The expected relationship of number of earners (NOE) in a household and fuel consumption is positive for electricity and gas but negative for other fuel sources. The estimates in table 1 mainly represent magnitude and direction for NOE with all dependent variables. Explicitly, electricity budget share has shown positive signs for NOE in Pakistan. It means that *ceteris paribas*, expenditure share of electricity increases by 0.0001 units with an additional earner in the family. As far as the gas share equation is concerned, negative relationship between gas budget share and NOE is depicted. Similarly, other fuels share equation also followed the expected signs. These values though very small are consistent with the results of Burney and Akhtar (1990) and Misra *et al.,* (1995). These results show that with more earning hands, greater income will be generated causing consumers to shift from consumption of inefficient fuel sources with efficient and better quality fuels. However, the opposite signs gained in gas share equations also points to the same fact but with different view. That is, as stated latter, all three fuels are necessities and normal goods, so with increasing level of incomes due to more earning member, households may behave to consume other luxury items that they are now capable of affording, ultimately reducing the

expenditure share of already consumed fuels at a certain level. These results are in line with the findings of Omer (2018).

House Size: The house size, i.e. the number of rooms in a dwelling is also identified in the literature to be a main factor behind households' fuel consumption in the country. Positive signs for all three equations in table 1 show that large houses with more number of rooms than average house are associated with high-energy consumption trends. This result is supported by outcomes of Misra *et al.* (1995) and Pachauri (2004).

Durable Commodities: It is perceived in literature that with increasing number of appliances and vehicles (durable items) owned by in a household, the consumption levels and so the budget share of energy sources used for the purpose increase. Keeping such thing in mind, the estimates of regression analysis are detected with strange and opposite results are yielded as compared to earlier studies.

Construction Type of the House: This variable is a dummy and expected to have positive sign for electricity and gas budget shares when the value is taken one for 'Pucca' house according to the material used in construction of walls. Positive estimates for Pakistan in case of electricity and gas budget shares are found to be consistent with logical reasoning. While, estimate in other fuel share has shown a negative but logically reasonable fact that if D_1=1 is considered for Pucca, than the expenditure share of fossil or low quality and inefficient traditional fuels consumption share is reduced for such households (Pachauri, 2004).

Uncompensated Own & Cross Price Elasticities: The Marshallian (uncompensated) own and cross price elasticities are computed here by using the parameter estimates gained in the estimation of LAIDS equations. As the study only includes three sources of fuel, namely electricity, gas and other fuels (FW & KO), the elasticities are also given for them in table 2. The diagonal bold values in the table present responsiveness of a household for a certain fuel item with respect to its own price changes. All other values show demand responses for relative price changes.

As can be seen, own price elasticity of electricity, gas and other fuels have come out to be less than one. All the three fuel items are inelastic commodities and have negative sign in in Pakistan. Thus, keeping other things constant, a percentage increase in price of electricity, gas or other fuels decreases the demand for each by less than proportionate figure. This result is consistent with economic theory and literature by Burney and Akhtar (1990); Idrees and Aziz (2013); and Omer (2018). Overall, electricity is the most inelastic fuel item with respect to its own price, followed by gas and then other fuels, the least inelastic one.

The results of cross price elasticities, as shown in table 2, reveal that electricity and gas are gross substitute of each other. The result contradicts what was found by Burney and Akhtar (1990). Still, Idrees and Aziz (2013) consider it to be true in certain circumstances where both can replace each other for accomplishment of everyday tasks. As far as other fuels are concerned, electricity and gas values of cross price elasticity with respect to them have come out to be negative and positive, respectively. So, it is stated that gas is a gross substitute of other sources of fuel, whereas electricity is used as a complementary good with other fuels.

Table 2

Marshallian Own and Cross Fuel Price Elasticities in Pakistan

Energy Source(s)	Electricity	Gas	Other Fuels
Electricity	-0.214	0.128	-0.004
Gas	0.128	-0.624	0.014
Other Fuels	-0.004	0.014	-0.627

Source: Author's calculation based on HIES 2015-16

Compensated Own and Cross Price Elasticities: The Hicksian or compensated demand elasticities (given in table 3) are also computed, which provide more realistic values for welfare analysis. The results found are more or less similar to those found in Marshallian part but the difference lies in their magnitude. As observed, all three fuel items to have theoretically consistent negative relationship with their own price. Electricity is gained to be most price inelastic fuel commodity, followed by other fuels and then gas. In terms of cross price elasticity, gas and electricity are again found to be a net substitute of each other at national level. Gas also acts as a net substitute of other fuels. Yet, electricity exhibits a net complementary relationship with other fuels.[7]

Table 3

Hicksian Own and Cross Fuel Price Elasticities in Pakistan

Energy Source(s)	Electricity	Gas	Other Fuels
Electricity	-0.220	0.121	-0.008
Gas	0.121	-0.584	0.014
Other Fuels	-0.008	0.014	-0.557

Source: Author's calculation based on HIES 2015-16

Expenditure Elasticities: Table 4 represents calculated expenditure elasticities using formulas given by Sulgham (2006). The total expenditure elasticity estimates for all considered fuel goods are less than 1 and positive showing that these three fuel sources are necessities and normal goods for Pakistan. As can be observed in the table, a percent increase in the total consumption expenditure of an average Pakistani household will increase their consumption of electricity, gas and other fuel sources by 0.81, 0.89 and 0.97, respectively. This means that other fuels are most sensitive ones to changes in total expenditures, followed by gas and electricity.

These findings are consistent with Engel's Law prediction that a less than proportionate value occurs for necessary goods in response to a percent change in expenditure of consumers. But, the positive sign outcomes make all three fuel categories as normal goods leading to their increased (decreased) budget share in case of positive (negative) income shock. Within fuel sources, the more inelastic nature of electricity and gas shows their expenditure share to fall to a lesser extent than the greater fall in expenditure share of fossil fuels in response to a reduction in the overall spending of a household. Considerably, the inelastic expenditure response would also imply that decrease in consumption expenditure will cause households to reduce their expenditure share of traditional fuels to a greater level as compared to gas and electricity. Thus, they will prefer not to reduce electricity or gas consumption as much as possible.

[7] See, for instance, Omer (2018), Burney and Akhtar (1990).

Table 4

Total Expenditure Elasticities for Pakistan

Fuel Source(s)	Fuel Elasticities
Electricity	0.81
Gas	0.89
Other Fuels	0.97

Source: Author's calculation based on HIES 2015-16

For electricity and gas, such a result is true in the sense that increase in income levels or expenditure capacity shows rising living standards creating more demand for fuel intensive goods or better living facilities and hence, more consumption of these two energy sources. These results are in contrast to the results of Burney and Akhtar (1990) and rather shocking for the category of traditional energy sources, other fuels. The possible reason for such outcome is the unavailability of electricity and gas infrastructure and its supply side constraints in many regions of the country. Further, energy crisis in terms of electricity supply problems throughout the year and the winter gas shortages in provided areas also created more demand for easily available fossil fuels in almost all parts of Pakistan.

Conclusions

Today energy consumption has become an essential component of total household consumption due to rapid economic growth and development. Households are trying hard to earn more to increase their living standards. Such increase encompasses huge demand for energy intensive products and processes employed by households for satisfaction of their daily needs. In this situation, Pakistanis are facing huge market failure in terms of high demand for modern fuels combined with shortages in their supply.

The main findings stressed the fact that electricity, gas and other fuels came out to be normal goods and necessities for Pakistani households. Similarly, the uncompensated and compensated own price elasticities showed all fuel sources are inelastic commodities having inverse relationship with their prices. The cross price elasticities presented electricity and gas to be substitutes. Other fuels came out to be a substitute of gas, but a complement of electricity. Household level scale economies were also found to be existed in all three share equations.

Different determinants including number of earners in a household and number of rooms in a dwelling, number of durable commodities owned by a household and construction type of the house, came out to have a significant impact in determining fuel budget share of households. But, in order to get more precise, reliable and logically consistent results, these factors should be regressed separately with dependent variables in a new model to avoid any effect of own or cross prices on the values of estimates.

Based on the results of the study, this is recommended that energy mixes should be familiarized to reduce the burden on one source of fuel. As all fuel items are inelastic commodities reflecting that their demand is high as compared to their supply. Thus, burden on conventional sources of energy in domestic sector should be reduced by introduction and implementation of new sources and technologies. Fuel sharing behaviors can be inculcated which will certainly help in economizing the rapidly growing energy consumption and benefiting the poor.

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