Selecting Correct Functional Form in Consumption Function: Analysis of Energy Demand at Household Level

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CERTIFICATE

This is to certify that this thesis entitled: **"Selecting Correct Functional form in Consumption Function: Analysis of Energy Demand at Household Level"** submitted by Mr. Faisal Abbas is accepted in its present form by the Department of Econometrics and Statistics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in **Master of Philosophy in Econometrics**.

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DEDICATION

I would like to dedicate this thesis to my family, friends and teachers who always supported me throughout all the rights and wrongs of my life.

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All glories to thee Allah, the omniscient and omnipotent and his Benediction be upon his prophet. The savior of mankind from darkness of ignorance a symbol to be and to do right. My deepest thanks of Allah the Almighty, who made me able to do this work.

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ABSTRACT

In the estimation of demand functions for energy resources, parametric econometric models of energy demand are commonly used to predict future energy needs. The functional forms commonly assumed in parametric energy demand models include linear functional forms, log-linear forms, trans-log models and almost ideal demand system. It is frequently debated which is the “best” functional forms to employ in order to accurately represent the underlying relationships between the demand for various energy resources and explanatory variables such as energy prices, income and other demographic variables. The recent interest has been focused on developing proper non nested tests to compare the two demand system, double log model and LA-AIDS model. C-test is used to test the validity of using the two parametric functional forms in models of residential energy demand. Cross-sectional household-level data of the Pakistan Social and Living Standards Measurement (Social & HIES) 2013-14 and Asian Development Bank (ADB) Asia and Pacific 2018 is used. We find that the LA-AIDS model is better than the double log model. Empirical findings suggests that if the population and GDP per capita grows every year than the household per capita demand for energy resources will rise over the next decade by maintaining prices constant.

Keywords: Energy demand, Double log model, LA-AIDS, C-test.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In empirical studies of consumption and production, functional form is a significant problem. Different functional types often lead to very distinct estimates of elasticity (Dameus *et al*., 2002) which ultimately lead to predict different future values and suggest alternative policy scenarios. The latest interest is concentrated on the development of an appropriate non-nested test of the two demand system. Elasticity estimates from different models such as an almost ideal demand system or log-log model are used to evaluate how price, tax, earnings, climate and other variables could affect demand (Zarnikau, 2003).

For predicting future energy requirements, parametric econometric energy demand models are widely used. The frequently assumed functional forms in parametric energy demand models include linear, log-linear, and trans-log functional forms. In linear models, different explanatory variables are supposed to have a straightforward linear fashion effect on energy demand. The dependent and explanatory variables are converted into natural logarithms in log-linear models and then regressed. From the estimated coefficient, elasticities can be easily achieved. To recognize their restricted theoretical basis, linear and log-linear models are sometimes referred to as ad hoc models. In comparison, in microeconomics theory, translog models have some foundations and are common in research literature. Examples of energy demand models such as double log model can be discovered in (Hussain & Asad, 2012) and (Idrees *et al.*, 2013) and for trans-log models of energy demand in (Uri, 1982). A range of other models are discovered in the scholarly literature, but less frequently used by practitioners, including types of Almost Ideal Demand Systems (AIDS), Symmetric

Generalized McFadden (SGM), and Generalized Leontief (GL) forms. In a previous paper (Zarnikau, 2003), frequently used non-parametric bootstrapping technique to compare functional forms of linear, log-linear, and trans-log share equation with a non-parametric function. The same exercise was repeated in (Xiao *et al.*, 2007) by using the same example application and data set of (Zarnikau, 2003) but using an alternative Bayesian technique.

In this analysis we are using another alternative approach developed by the (Davidson & MacKinnon, 1981) which is known as C-test. Under the null hypothesis that the double log model for elasticity estimation is correct functional form. This approach is used by (Alston *et al.*, 2002) for the estimation of compensated double log demand model by deflating the income variable alone using Stones price index. The compensated form has the same right-hand side as a single-equation version of the popular linear approximation to the Almost Ideal demand model, facilitating the construction of a test for choosing between the two alternatives. This study determines these results, develops the specification test, and illustrates its application using Pakistan energy consumption data.

Energy is a major economic sector and plays a crucial role in the economic development of the country. In the past, Pakistan's economy was faced with energy-side blockages that had restricted its growth and development. Pakistan's energy demands are growing quickly as a developing economy. In addition to the growth of natural resources and minerals, the state is attempting to guarantee the accessibility and safety of renewable energy, petroleum and gas supply. Pakistan is gradually moving to a decarburization system and concentrating more on renewable energy sources in accordance with the Paris Climate Agreement to reduce emission intensity. The government demonstrates dedication through renewable energy sources to generate electricity. Renewables currently account for only two percent of electricity generation, although they are anticipated to rise in the coming years.

In the energy sector, energy consumption per capita is regarded to be one of the most significant indicators of economic welfare in terms of accessible energy supply. In terms of consumption among different consumer classes, the domestic sector (residential consumers) showed the greatest increase in energy use between fiscal year 1992 and fiscal 2006; this sector’s energy consumption grew at an annual rate of 5.4 percent (ESMAP, 2006). The consumption pattern of electricity has not changed significantly over the past year, although households ' share of electricity consumption has risen marginally to 51 percent. This was offset by a decrease in industry's share of energy usage by one percent. During FY 2016-17, the country's annual consumption of petroleum products was around 26 million tons. 60.4 million barrels of crude oil were imported during July-Feb FY 2017-18, while 21.8 million barrels were extracted locally. Only 15 percent of the country's total requirements are met by indigenous crude oil, while 85 percent are met by imports in the form of crude oil and refined petroleum products (Pakistan Economic Survey 2017-18).

Coal is known as one of the cheaper sources in terms of electricity generation costs (Rs / Kilowatt hours). Gas is also a less expensive source as it is an economical and effective fuel compared to other oil goods, the national government began importing LNG in the first quarter of 2015. In the case of natural gas, the gap between supply and demand widened owing to increased demand for gas and depletion of current sources. Natural Gas is a fuel that is clean, secure, effective and friendly to the environment. Their indigenous supplies make up around 38 percent of the country's complete primary energy production mix. The government is following its policies to boost indigenous gas manufacturing and import gas to satisfy the country's growing demand for energy. The average consumption of natural gas During July-Feb 2017-18, was about 3.837 million cubic feet per day (MMCFD), including 632 (MMCFD) volumes of Regasified Liquefied Natural Gas (RLNG), compared to 3.205 (MMCFD) last year (Pakistan Economic Survey 2017-18).Pakistan has big reserves of indigenous coal estimated at over 186 billion tons that are adequate to satisfy the country's long-term sustainable energy demands. Imports of coal have increased significantly as new coal-based power plants have been commissioned in Sahiwal and Port Qasim.

Recently, technological advancement, demands for renewable inclusion and aging infrastructure have made energy forecasting more important for activities in the energy system. Management of energy demand is needed to properly allocate available resources. In Pakistan's case, there is a significant gap between electricity demand and supply despite the government having done lots to mitigate this. Now issue is that, is this a supply side phenomenon or errors in demand measurement of the households or the forecasting issues? So, idea is to explore the true pattern of household energy consumption by using the household level data.

1.2 Objectives

The purpose of this study is

1. To test whether the double log functional form or linear approximation of the almost ideal demand system (LA-AIDS) provides sensible descriptions of the real functional connection of Pakistan's household level demand for fuel[11] energy, other fuels, and multiple explanatory variables.
2. **2.** To project the future level of energy demand in terms of income elasticities through simple growth model.

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[1] [1] Expenditures on different types of fuel –firewood, kerosene oil, natural gas, cylinder gas, diesel and other-fuels. The other fuels category includes household expenses on coal and other biomass fuels such as dung cakes and crop residue.

1.3 Hypothesis

Non-nested hypothesis tests select between two regression models where one model cannot be written as a special case of the other. Two non-nested designs are here, double log model (A) and LA-AIDS (B), with the same right hand side of independent variables to choose from using the same set of data. For two non-nested models that model (A) is the true model, hypotheses can be written as:

1) H_o: The double log model is correct under the null hypothesis. (Model A)

   $H_{1:}$ Alternative hypothesis that AIDS is correct. (Model B)

2) H_o: Income and price elasticity have a significant effect on energy demand.

   $H_{1:}$ Elasticities of income and price are inelastic on the demand for energy.

1.4 Significance of the study

- Which one is the correct functional form to estimate the elasticities of price and income from two alternatives model (double log and AIDS).
- What is the upcoming level of energy demand in Pakistan? Because demand for these fuels is rising day by day, the management of energy demand is necessary to properly allocate the available resources. Recently, technological advancement, demands for renewable inclusion and aging infrastructure have made energy forecasting more important for activities in the energy system.

1.5 Organization of the study

The study is structured into five sections or chapter, Chapter one provides a short overview of the study covering the research problems, goals and hypothesis. Chapter two reviews relevant literature. Chapter three discusses the methodology and data. Chapter four presents empirical results and discussion. The final section discuss the findings and suggestions.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

Literature review gives foundational, theoretical and empirical background and effective information to comprehend the depth and significance of a study problem. Reviewing past studies is therefore one of the first steps to understand, evaluate and solve a research issue. Previous studies on right functional form in energy modeling, energy demand analyzes and their predictions have been evaluated in chronological order in the subsequent chapter.

2.2 Previous studies for correct functional form

Dameus et al. (2002) constructed a parametric bootstrap test to choose between the linearized version of the Almost Ideal Demand System (FDAIDS) First-Difference and the model search in Rotterdam. It is known that parametric bootstrap tests have excellent size and performance characteristics, while low power is available for encompassing test. The new approach was used to select between the FDAIDS and Rotterdam models for U.S. meat demand. With the parametric bootstrap, the FDAIDS was consistently rejected in favor of the Rotterdam model. Thus, the results support using the Rotterdam model for U.S. meat demand. Another drawback of the comprehensive test is that the compound model converted to a local rather than a global optimum in one instance.

Zarnikau (2003) compared the functional forms in demand for energy modeling. He compared linear, log–linear and translog share equation functional forms. Bootstrapping techniques are used in residential energy demand models to assess the validity of using the three parametric functional types. Using cross-sectional household-level information from the U.S. Labor Statistics Bureau (US BLS), consumer spending survey, and other public data sets. Based on the assumption that a non-parametric kernel regression estimator may provide an ideal, or at least better, description of the fundamental relationship between electricity consumption and a series of four prevalent independent variables, three popular parametric model specifications were screened and dismissed at ordinary significance levels. Every one of the parametric functional forms investigated perform badly, implying that they may not be flexible enough to deliver relevant outcomes in some implementations. These findings indicate that when making judgments about the functional form of energy demand systems, caution should be undertaken.

Xiao et al. (2007) used the Bayesian method to evaluate what are the "best" functional forms to use in order to better depict the fundamental relationship between the consumption of different energy resources and explanatory variables like power prices, weather variables, earnings and other variables in US demand for electricity. Excellently-known model choice measures including the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) restrict Deviance Information Criterion (DIC) examples. They evaluate household energy consumption using cross-sectional family level information, a DIC comparison for four excellently-known models demonstrates that almost ideal demand system and translog models are competitive to a double log model that is superior to the linear functional form in general.

Previous studies estimated the function of demand in accordance with economic theory. Most implemented flexible functional forms that depend strongly on the theory of duality. The most prominent demand systems are the generalized Leontief, translog, Rotterdam models and the almost ideal demand system (AIDS). Their functional shapes are regionally flexible because at a specified stage they do not place a priority constraints on possible elasticity. They also use adequate variables at a specified stage to estimate elasticity; moreover, local elastic functional forms frequently display small regular areas in accordance with macroeconomic theory.

2.3 Previous energy demand studies for Pakistan

Acknowledging the production and consumption factors and their determinants in the energy industry is crucial because it directly effects our daily life since we have become reliance on the use of electricity-driven devices. The subject of demand side management has acquired significant importance in the context of the present energy shortage. Regarding its importance, there was no significant work on residential-level information on the demand for energy in Pakistan. Maybe because energy consumption was treated as "provided" or clearly defined. Whatever the cause may be, Pakistan is still waiting to explore the demand side of energy. We still need to create understanding into the mechanics of our country's energy demand. There are several researches which have addressed the issue of demand for energy for national, industrial and commercial consumers. A few of the residential energy demand focused studies are discussed here.

Siddiqui (1982) examined Pakistan's household consumption pattern by using the 1971-72 HIES information with 1968-69 and 1971-72 pooled information. She provided a linear and log linear relationship between fuel and lighting consumption, household size and earnings. In the context of clothing, housing, fuel and lighting, the research findings placed validity checks for Engel's law. The comparative shares of total clothing and accessories, fuel and lighting expenditure and various expenditure in urban regions are not very distinct from rural ones. However, spending on urban housing exceeds that in rural regions significantly.

Burney and Akhtar (1990) used data from the 1984-85 household integrated economic survey (HIES) to analyze the trend of household spending on energy consumption in

Pakistan. They used Extended Linear Expenditure system to evaluate price and income elasticity. The research findings indicated that almost all fuels were inelastic in price and income, implying for rural and urban residents respectively these were necessities. In addition to earnings and price, there are many other variables such as household size and social-economic variables that have important effect on the consumption of household fuel but have not included these factors in their study.

Iqbal and Jamal (1992) used Extended Linear Expenditure System (ELES) and found, insignificant variation in the marginal budget shares and subsistence expenditure among all provinces except for transport in rural Baluchistan and rent in urban Punjab. The information are extracted from the 1986-88 household integrated economic survey. The model's significant weakness is that the estimated marginal budget shares are consistent with changes in income. Whereas the ELES is simple to use, it assumes additive preferences, significantly limiting the options of replacement and also excluding inferior goods.

Amur and Bhattacharya (1999) explained the status of biomass energy use in Pakistan. Moreover, accurate estimates of the use of biomass energy in separate sectors of the economy are not accessible, as in most developing countries. It has been estimated that around 65.07 billion kg of firewood production is equivalent to 22.57 million tons of oil equivalent (MTOE) and accounts for 44% of the country's total main energy requirement. The residential home field is the leading consumer and uses up 86% of amount of energy from biomass. The traditional cook stoves are the main consumers of renewable energy and about 80% of the total amount they consume.

Khan and Ahmad (2009) reviewed Pakistan's disaggregated power requirement (gas, electricity, and coal) over the 1972-2007 era. Their primary findings indicate that the consumption of electricity and coal is responding positively to fluctuations in real GDP per capita and national price level would be negatively effect. Gas consumption reacts negatively to short-term real income and price modifications, but in long-term real income has a positive impact on gas usage, while national price stays negligible. In addition, the average price elasticity and real gas consumption income (in absolute numbers) are higher in the short run than those of electric power and oil demand. Each energy component's variations in elasticity have important policy consequences for earnings and generating revenue.

Khan and Qayyum (2009) reviewed Pakistan's trends of electricity demand over the 1970–2006 era. They used to cointegration auto regressively distributed lag method. At domestic level and in the three main classifications of customers such as homes, business and agriculture the long-term and short-term price and revenue elasticities are examined. The general findings indicate that in the long run as well as in the short term, revenue and price elasticity have anticipated indications at cumulative and disaggregate rates. In addition, over the sample period, the estimated long-term and short-run electricity demand features remain constant. The findings thus transmit significant data about pricing strategies to the agents working on the electricity market and help to plan the future demand management strategy for electricity.

Chaudhry (2010) investigated the reactions of residential electricity demand to revenue modifications to help policymakers in controlling electricity demand and assessing tariff rises connected with suggested projects to increase supply while minimizing the effect on hunger. For 2003/04, they used Punjab Multiple Indicators Cluster Survey (MICS) data. The MICS has information on appliance owning, accommodation and household features (such as number of members of the household and number of rooms in living space) and per capita income and expenditure for over 30,000 households, in addition to the required information on electricity expenditure. Their findings shows that demand for electricity is positively dependent on both income and ownership of the appliance. Appliance owning has dramatically increased and almost all families have contacts to electricity.

Khattak et al. (2010) studied the function of financial and non-economic variables in determining the electricity requirement of homes in Peshawar district. During November-December 2009, primary information were gathered from 200 City Rural Division homes for this purpose. To drive estimates, they used the Multinomial logistics model. Findings showed that household energy demand is often influenced by revenue, family education, number of bedrooms, and climate change. The electricity price also impacts the demand for electricity, but only for customers with a relatively smaller monthly consumption of electricity.

Hussain and Asad (2012) established residential electricity expenditure determinants in Pakistan. By using household information from the Pakistan Social and Living Standard Measurement Survey (PSLM) (2004-05), they find out the determinants of consumption spending on electricity. To assess the elasticity of all explanatory variables the double log functional form was used, such as household income, household size and rooms of the house, area and energy-consuming equipment such as Air conditioning, refrigerator, freezer, computer, washing machine and water cooler. They observed that electricity expenditure is revenue inelastic, household size rises, as well as the number of bedrooms tends to increase electricity spending. Compared to rural homes, families residing in urban regions have more electricity spending. Households in Punjab's urban and rural regions have higher spending on electricity relative to other provinces. The purchase of electrical equipment made a significant contribution to the spending on electricity. The two strongest participants are Freezer and air collar.

Idrees et al. (2013) estimated demand for electricity through multiple functional types including linear, logarithmic linear and trans-log functional models, thus analyzing all three functional types, particularly for Pakistan. For the years 2004-05 and 2007-08, they used the micro-level data from the Pakistan Social Living Standard Survey (PSLM). Their results indicate that total spending, size of the household, size of the family, days of heating degree and above-threshold temperature can boost electricity demand. At the other side, electricity prices may reduce electricity consumption. An analysis of elasticity demonstrates that gas is a empirical replacement for electricity.

Javid and Qayyum (2013) examined the interactions between electricity consumption, actual economic activities, actual electricity prices and the fundamental energy consumption pattern at the overall and sectorial level, namely for the domestic, industrial and commercial industries. A function of electricity demand for Pakistan is evaluated by implementing the method of the structural time series to annual information from 1972 to 2010. Their findings indicate that the existence of the pattern is formally stochastic rather than linear and deterministic. The underlying energy demand trend demonstrates an upward path for the use of electricity in business, industrial and residential industries. This UEDT upward slope indicates that other exogenous variables outweigh either energy-efficient equipment has not been implemented in these industries or any improvements in energy efficiency owing to technical advancement.

Naz and Ahmad (2014) used the conditional demand model to evaluate household demand for electricity through post-use of electricity consumption and used Logistic regression to evaluate family financial and social features as determinants of current electricity crises. They had to use cross-section information collected from all five Karachi districts through a household energy survey. The findings of the Conditional

Demand Model estimate indicate that the demand for electricity in urban homes is determined by the end uses of electricity consumption and also differs by family head gender. The research indicates the function of demand side planning by encouraging local innovation in electricity-efficient equipment manufacturing, encouraging residential-level electricity protection, and laws toward energy stealing to tackle the power shortfall issue.

Khan *et al.* (2015) analyzed inter-temporal patterns of household consumption expenditure on different forms of energy in Pakistan. They used the micro level data of the Pakistan Integrated Household Survey (PIHS) 2001-02 and Pakistan Social and Living Standards Measurement (PSLM) Survey 2010-11Using the Extended Linear Expenditure System, income elasticity of various kinds of fuels was calculated. The analysis shows a differential pattern of energy use across the urban and rural areas of the country as well as changes over time, with rural households spending proportionately more on fuels throughout this period. The income elasticity for distinct fuels was discovered to be lower than unity, suggesting that for both urban and rural homes, all fuel kinds are a necessity. In both sample phases, firewood, kerosene oil and other fuels are discovered to be superior fuels for urban homes. All estimated own price elasticities, though small in magnitude, was found to have the expected negative signs with few exceptions (firewood, kerosene oil and other fuels).

Hussain et al. (2016) forecast complete energy usage and its elements for Pakistan up to 2020, such as household, other government, and agriculture, street light, industrial and commercial sectors. From 1980 to 2011, they implemented Holt-Winter and Autoregressive Integrated Moving Average (ARIMA) models on secondary time series data to predict cumulative and part wise consumption of electricity in Pakistan. Their findings show that demand in the domestic industry would be higher than in all other industries, and the rise in power supply would be lower than the rise in total energy usage over the predicted era.

Irfan et al. (2017) estimated energy spending and family fuel cost elasticity in Pakistan. It is depleting forests, natural gas and other reserves of energy. They pooled three information sets (2007-08, 2010-11 and 2013-14) of Pakistan's Social and Living Standard Measurement Survey (PSLM). They reported our data set doesn't have market price information, and the LA-AIDS model is widely used for this type of data set because all households are assumed to have the same prices fixed for this model. In addition, the LA-AIDS model is relatively simple to assess and interpret and accurately fulfills the theorems of selection. They discovered that all kinds of fuel excluding natural gas were inelastic prices at the domestic and urban household's level. Fuel expenditures elasticities for all fuels were found to be positive and between zero and one.

2.4 Previous energy demand studies form world

Houthakker (1951) used cross-sectional information on 42 provincial cities for a period from 1937-1938 to study some calculations on energy usage in Great Britain. He used OLS method to compute log-log models involving variables such as; average annual household electricity consumption with a two-part tariff decrease, median income, average electricity prices, marginal gas prices, and average household ownership of power-consuming devices.

Berndt and Samaniego (1984) measured residential electricity demand in Mexico. They used the double log model to estimate the quantity demanded is specified to be a function of prices, income, and other socioeconomic variables. They used pooled cross-section time series data set for the six regions of Mexico over the 1970-78 time period. One of the main findings of this article is that, for a developing nation such as

Mexico, revenue rises have a significant effect on energy consumption, firstly in terms of raising the amount of homes connected to electricity facilities, and secondly in terms of rising the utilization of those homes already accessing electricity.

Westley (1984) analyzed the electricity demand in a developing country. In ten areas in Paraguay from 1970-1977, they evaluate housing and commercial demand for electricity. Models estimated in the parameters that are both linear and nonlinear. The nonlinear approach requires benefit of background knowledge about the nature of the devices to be used and, at the same time, addresses the discontinuities of demand created by unknowability of the devices. Three dynamic models, including a novel model of cumulative adjustment, all show fast adjustment to the required inventory concentrations of the appliance. Finally, to assess the welfare expense of energy outages, the multi-product excess loss gained from an estimated demand equation is used.

Plourde and Ryan (1985) examined some theoretical issues on the use of double-log functional forms in energy demand analysis and note a few related problems. First, they examined some of the theoretical underpinnings of double- log demand functions. Second, they claim that one of the contributions of their study is "an approach to derive demand functions that could be used to derive similar functions for other types of goods and services, besides electricity". Third, their study accidentally reveals a number of problems that arise when the dominant concern is obtaining demand equations of the double-log form. Therefore, the suggestion that their methodology be used to derive double-log demand functions for other goods and services is ill-advised. The disadvantages of this functional form and the fact that its main advantage constant and easily estimated elasticities seems undesirable would appear to be convincing reasons for considering the use of alternative function.

Branch (1993), based on the Consumer Expenditure Survey (CE) of the Bureau of Labor Statistics, U.S., provided details on the connection between revenue and electricity usage. The log-log functional is used to evaluate income elasticity, energy prices, housing, demographic features, seasonal factors, weather conditions, kinds of heating devices and electricity-using appliances using homeowners ' household panel data. The CE is affluent in information on household attributes, information on residential characteristics, and information on the inventory of appliances. This allows for more robust modeling of electricity demand across sectors in the U.S. than was performed in a number of previous research. The findings achieved using a generalized least square (GLS) method to calculate, include a 0.23 income elasticity of electricity demand and a -0.20 price elasticity.

Filippini and Pachauri (2004) investigated residential energy demand for all of India's metropolitan regions. Cross-section data for the year 1993-94 containing 30,000 families was used. They used monthly information for summer, winter and monsoon seasons to estimate three demand features in log form. The factors included were average electricity prices, kerosene prices, LPG prices, actual household spending, and household space covered, area size, family size, and family age. They did not provide the households ' data about the appliance. Their findings indicate that in all three seasons the demand for residential electricity is earnings and cost inelastic, while regional, family and demographic factors included show important effect on the demand for electricity.

Holtedahl and Joutz (2004) examined the residential demand for electricity in Taiwan as a function of household disposable income, population growth, the price of electricity and the degree of urbanization. The equipment-based productive capacity of energy can be split into two kinds. The first meets the requirement for day-to-day power facilities: lighting, cooling, servicing and leisure. The second concerns changes in weather conditions, which may influence the requirement for heating and refrigeration services. Short- and long-term effects are separated through the use of an error correction model. In the long-run, the income elasticity is unit elastic. The impact on the price of one's own is negative and elastic. The impacts of cooling degree-day have a positive effect on short-run usage. They was using a variable proxy, urbanization, to detect characteristics of economic development and alterations in income-free capital stocks that use electrical energy. The determinant gives the model considerable explanatory power in both the short and the long term. They describe it as influencing variables not covered by the simple income effect for economic development and believe it looks very promising in other developing countries to explain residential electricity consumption.

De Vita et al. (2005) estimated the long-run elasticity of the Namibian energy demand function for the era 1980 to 2002 at both aggregate rate and power type (electricity, gasoline and diesel). Their primary findings indicate that energy consumption is a positive response to GDP changes and a negative response to changes in energy price and air temperature. Namibian policymakers have important consequences for energy taxation due to variations in price elasticity across fuels revealed in this research. They discover no important elasticity of cross-price between distinct kinds of fuel. They seem to get ‘locked’ into a set of appliances and equipment for the provision of the energy services they require and do not easily break away from that pattern even if prices and income change.

Gundimeda and Köhlin (2008) used micro data of more than 100,000 households sampled across India by using linear approximation of almost ideal demand system (LA-AIDS). The price and expenditure elasticity of Marshallian and Hicksian demand for four primary fuels (fuel wood, kerosene oil, electricity and LPG) are estimated by separate earnings groups for both urban and rural regions. They classify the complete household spending as a proxy rather than income. As household-level prices are recorded in the information, unit values for all fuels have been imputed as price proxies by separating commodity spending by the respective bought amount. The benefit of the LA-AIDS model is that in the structural parameters the demand model is linear.

Mittal (2008) used AIDS to estimate the elasticities of price, income and other explanatory variables and they used simple growth model for demand projection to present the supply, demand trends in India. The projections were based on change in yield levels, changes in price, growth of population and income growth. For the years 1983, 1987-88, 1993-94, 1999-2002 and 2004-05, the information for this research were drawn from different National Sample Survey (NSS) round survey. The results showed that the total demand of food was increase due to growth in population and per capita income.

Ngui *et al.* (2011) estimated price and fuel expenditure elasticities of demand by applying the linear Approximate Almost Ideal Demand system (LA-AIDS) to 3665 households sampled across Kenya in 2009. The model LA-AIDS is linear, flexible and meets the demand theory axioms. It is derived from a well-behaved utility function and hence is consistent with demand theory. On average, at the moment of the study, 10–15% of families did not use at least one kinds of fuel. The cost must be accessible for all kinds of fuel for all residents to account for the fuel expenditure function and the total system of fuel share models. Therefore, as a proxy for missing price, they used the average price of that specific type of gas within the same cluster / town. The results show that kerosene oil is an elastic income, whereas fuel wood, charcoal, LPG, electricity, motor spirit premium (MSP), automotive gas oil (AGO) is an inelastic income.

Sun and Ouyang (2015) estimated price and expenditure elasticities of residential energy demand using data from China's Residential Energy Consumption Survey (CRECS) that covers households at different income levels and from different regional and social groups. The Almost Ideal Demand System Model was scientifically used to predict consumer demand elasticity. The Almost Ideal Demand System model's fundamental concept is to reduce actual consumer spending under the specified price and utility rates. Empirical results from the Almost Ideal Demand System model are in accordance with the basic expectations: the demands for electricity, natural gas and transport fuels are inelastic in the residential sector due to the unreasonable pricing mechanism.

2.5 Summary and literature gap

The studies discussed above employed various data sets and models to address various issues relating to energy demand and its projection for different countries and for different regions. Frequently used non-parametric bootstrapping techniques and Bayesian approach to compare linear, quasi-linear, and trans-log share equation functional types in previous studies such as Zarnikau, (2003) and (Xiao et al., 2007). In this study we are using another alternative approach developed by the (Davidson & MacKinnon, 1981) under the null hypothesis that the dual log model is the correct functional form for elasticity estimation, which is known as the C-test.

Earlier studies had also reported the role of consumption in accordance with economic theory. Most have embraced flexible functional forms which depend strongly on the theory of duality. The linear functional form, log linear functional form used by Houthakker (1951), Berndt and Samaniego (1984), Branch (1993), Siddiqui (1982), Hussain and Asad (2012) and Idrees *et al.* (2013) and the almost-ideal demand system (AIDS) used by Mittal (2008), Gundimeda and Köhlin (2008), Ngui *et al.* (2011), Sun and Ouyang (2015) and Irfan *et al.* (2017) these are the most common models of demand. These functional forms have been chosen on subjective criteria to assess the price and income elasticity of different fuels, but now this study's contribution is to build a test to choose between the two solutions. This study determines these results, develops the specification test, and illustrates its application using Pakistan energy consumption data. On the other hand, most of the studies and literature shows that the demand for different type of fuels and electricity is increasing day by day so energy demand management is required for proper allocation of the available resources. Recently, technological advancement, demands for renewable inclusion and aging infrastructure have made energy forecasting more important for activities in the energy system.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The focus of this chapter is to present the theoretical framework of demand system, its econometric representation and the discussion of data. Following the introduction this chapter has four additional sections, section 3.2 describe theoretical framework. Section 3.3 discussed methodology developed for this study. Section 3.4 deals with energy commodities and data sources. Section 3.5 describe the econometric modeling.

3.2 Theoretical background on demand analysis

Household demand evaluation is essentially the act of analyzing customer preferences in such a way that customers choose to divide their revenue between several distinct commodities. The term of utility is used in theory of economics to describe the amount of satisfaction resulting from the particular allocation of revenue among different goods. The demand of household is analyzed by using numerous models from which most common are double log functional form and linear approximation of almost ideal demand system.

3.2.1 Double log model

A logarithmic-demand model indicates the logarithmic amount demanded as a function of logarithmic income- and price-elasticity factors acting as coefficients known as double-log demand function,

$$lnQ_i = \alpha_0 + \sum_{j=1}^{n} \alpha_{ij} \; lnp_j + \alpha_m \, lnI \qquad (3.1)$$

This is uncompensated or Marshallian demand system where Q_i is quantity demand for specific commodity, p_j is the prices for good j, I shows the income or expenditure of N goods, α_{ij} are the own price and cross price elasticities and α_m is income elasticity which are directly estimate from double log model. Because of this particular feature, the double-log or log linear model is also known as the constant elasticity model (because the regression line is a straight line in the Q and P logs, its slope is constant throughout, and the elasticity is also constant, it doesn't matter at what value this elasticity is calculated). By applying ordinary least squares (OLS) to cross-sectional or time series data, the coefficients of the double log model can be easily estimated.

3.2.2 Compensated double log demand function

Obtaining Hicksian or compensated demand elasticity measures is desirable. Stone (1954) proposed the Slutsky equation in elasticity from these can be deduced from Marshallian elasticity using the Slutsky equation to achieve compensated demands,

$$\alpha_{ij} = \alpha_{ij}^{*} - \omega_j \alpha_m I \qquad (3.2)$$

Where α_{ij} is the uncompensated or Marshallian price elasticity of demand for good i with respect to P_j, α_{ij}^{*} is Hicksian or compensated price elasticity price elasticity of demand for good i with respect to P_j, ω_j is the budget share of good j and $\alpha_m I$ is income elasticity of good j.

By putting equation (3.2) in equation (3.1) we get compensated double log model,

$$lnQ_i = \alpha_0 + \sum_{j=1}^{n}[\alpha_{ij}^{*} - \omega_j \alpha_m I]\ lnp_j + \alpha_m\ lnI \qquad (3.3)$$

$$= \alpha_0 + \sum_{j=1}^{n}\alpha_{ij}^{*}\ lnp_j + \alpha_m[lnI - \sum_{j=1}^{n}\omega_j\ lnp_j] \qquad (3.4)$$

$$= \alpha_0 + \sum_{j=1}^{n}\alpha_{ij}^{*}\ lnp_j + \alpha_m\ ln(\frac{I}{p^{*}}) \qquad (3.5)$$

Where the geometric price index P* is Stone index:

$$P^{*} = \omega_1 lnp_1 + \omega_2 lnp_2 + \omega_3 lnp_3 \dots\dots + \omega_n lnp_n \qquad (3.6)$$

$$P^{*} = p_1^{\ \omega 1} + p_2^{\ \omega 2} + p_3^{\ \omega 3} \dots\dots\dots + p_N^{\ \omega N} \qquad (3.7)$$

The equation (3.5) of double log model represents a compensated or Hicksian demand function, in the sense that its price coefficient are compensated elasticities. This is a double log model in which the prices are undeflated and the nominal expenditures are deflated by stone's price index accordingly define in equation 3.6, for the commodities included in the model.

3.2.3 Almost Ideal Demand System (AIDS)

A famous Hicksian demand feature called the Almost Ideal Demand System (AIDS) model created by Deaton & Muellbauer (1980) is used to avoid the issue of steady marginal budget shares. Using the expenditure function and price-independent generalized logarithmic (PIGLOG) preferences, they obtained the AIDS model.

The PIGLOG preferences group is the price or expenditure function that specifies the minimum expense needed to reach a particular amount of utility at the specified prices. For utility u and price vector p, we refer to this function e (u, p) and describe the PIGLOG group by,

$$Log\ e(u,p) \ = \ (1-u)\ log\ a(p) \ + \ u\ log\ b(p) \tag{3.8}$$

With some exemptions u lies between 0 (subsistence) and 1 (bliss), so that the positive linearly homogeneous functions a(p) and b(p) may be considered, respectively, as the cost of subsistence and bliss. Taking functional forms available to log a(p) and log b(p) as

$$Log\ a(p) \ = \ \alpha_O \ + \ \sum\alpha_k\ log\ p_k \ + \ \frac{1}{2}\ \sum\sum\gamma_{ij}\ log\ p_k\ log\ p_j \tag{3.9}$$

$$Log\ b(p) = \log a(p) + \ \beta_0\ \Pi\ p_k{}^{\beta k} \tag{3.10}$$

Finally the almost ideal demand system is written as,

$$Log\ e(u,p) = \alpha_0 + \sum\alpha_k logp_k + \frac{1}{2}\sum\sum\gamma_{ij}logp_k logp_j + u\beta_0\Pi pk^{\beta k} \tag{3.11}$$

Where parameters are αi, βi and γij. It can be easily verified that e(u, p) is linearly homogeneous in p as long as all the demand function restrictions must hold. The partial derivative of expenditure function in terms of price, according to Shephard Lemma, is similar to the ideal compensated demand measured by price and utility (Hicksian demand).

The demand function can therefore be obtained as follows:

$$\frac{\mathrm{de(u,p)}}{\mathrm{dp_i}} = q_i \tag{3.12}$$

Multiplying both sides by p_i/e (u, p) we find,

$$\frac{d\ log\ e(u,p)}{d\ log\ p_i} = \frac{p_i q_i}{e(u,p)} = \omega_i \tag{3.13}$$

Where ω_i is the budget share of good i. By taking the partial derivative of expenditure function in equation (3.11) in terms of logarithmic prices yields

$$\omega_i = \alpha_i + \sum \gamma_{ij}\ log\ p_j + \beta_i log(\frac{x}{P}) \tag{3.14}$$

Where $\gamma_{ij} = \frac{1}{2}(\gamma_{ij} + \gamma_{ji})$ and x/p is real spending on all commodity group.

Where p is an index of prices,

$$Log\ a(P) = \alpha_0 + \sum \alpha_k\ log\ p_k + \frac{1}{2}\sum\sum \gamma_{ij}\ log\ p_k\ log\ p_j \tag{3.15}$$

Equation (3.15) Shows the mixture of linear and non-linear rates and is also known as the Quadratic almost ideal demand system (QA-AIDS), but Deaton & Muellbauer (1980) linearized the Almost Ideal Demand System model with the Stone price index and built the linear demand system (linear approximation of almost ideal demand system),

Log a (p) = log (p), equivalent to stone price index accordingly define in equation 3.6. By deflating the income by stone price index and imposing homogeneity restriction we get linear almost ideal demand system (LA-AIDS) as shown below:

$$\omega_i = \alpha_i + \alpha_{i1}\ln(p_1) + \cdots + \alpha_{iN}\ln(p_n) + \alpha_m \ln(\frac{I}{P^*}) \tag{3.16}$$

The restrictions on the parameters of the AIDS budget share equation. We take these in three sets such as adding up, homogeneity and symmetry restrictions which are shown below respectively:

1. $\sum\alpha_i = 1, \sum\alpha_{ij} = 0$ and $\alpha_m = 0$ ....(3.17)

2. $\sum\alpha_{ij} = 0$ ....(3.18)

3. $\alpha_{ij} = \alpha_{ji}$ ....(3.19)

Provided above three characteristics hold budget share equation of LA-AIDS reflects a system of demand functions adding up to total expenditure shares (∑wi = 1) are homogeneous of degree zero in prices and total expenditure combined and satisfying Slutsky symmetry. 2nd property in equation (3.18) is homogeneity where the sum of all the own price, cross price and income elasticities are equal to zero, 3rd property is Symmetry condition. Given these, the AIDS is simply interpreted as: in the absence of changes in relative prices and real expenditure (x / P) the budget shares are constant and this is the natural starting point for predictions using the model. Changes in relative prices work through the terms γij which indicate the effect on the ith budget share by 1 percent increase in the jth price with (x / P) held constant. Changes in real expenditure operate through the α_m coefficients these add to zero and are positive for luxuries and negative for necessities. The AIDS model could be used to construct demand equation systems that can be calculated across specifically defined commodity groups. Because budget shares are not constant changes in income elasticity with changes in income.

By taking the derivative of equation (3.16) w.r.t prices we get uncompensated own price and cross price elasticities where i= 1 for own price and i= 2…n for cross price elasticities for good one,

$$\in_{ij} = \frac{\alpha_{ij}}{\omega_i} - \frac{\alpha_m}{\omega_i} - \sigma_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.20)$$

When $i = j$ than $\sigma_{ij} = 1$ which will be own price elasticity and if $i \neq j$ than

$\sigma_{ij} = 0$ which will be uncompensated cross price elasticity.

For expenditure or income elasticity we take the partial derivative of equation (3.16) w.r.t income which yields the income elasticity,

$$\eta_i = 1 + \frac{\alpha_m}{w_i} \quad \text{...} (3.21)$$

Where η_i is income elasticity and if the coefficient of logarithmic income (α_m) is positive than income elasticity will be greater than 1, that commodity is luxury. If income elasticity is less than 1 and positive than the coefficient is negative and commodity is necessity. The commodity is unitary elastic if $\alpha_m = 0$. It also demonstrates above equation that if the commodity is a luxury or a necessity, the income elasticity of the good will decrease as income rises. This is due to the reality that necessities ' budget shares (ωi) are declining as income rises, while luxury budget shares are increasing as income rises. With variations in income, income elasticities stay unchanged in the scenario of unitary elasticities. This is because budget shares are not changing as income rates change for unitary elastic products.

King (1979) indicated that the selection of demand model is of main interest in consumer analysis since it has a direct connection to the nature of the variables or elasticity achieved. There are two demand features for the current research: first, double log demand function, and second, LA / AIDS, both of which are discussed in detail above. There is a subjective criteria that Because of its theoretical supremacy, we preferred LA / AIDS to be flexible in permitting but not requiring overall demand theory restrictions but double log demand function also fulfill the restrictions of the demand theory and its parameters to estimates gives direct elasticities, so the contribution of the present study is to encompass these two demand function for the correct functional form through the C-test by Davidson and MacKinnon (1981).

3.3 Test for the correct functional form

The right side of the compensated double log model in equation (3.5) where income is deflated by stone's price index is similar to the equation of the popular linear approximation of the Almost Ideal demand system in equation (3.16) with the expense share of the good $_i$ as the dependent variable instead of ln Qi:

$$\omega_i = \alpha_i + \alpha_{i1}\ln(p_1) + \cdots + \alpha_{iN}\ln(p_n) + \alpha_m \ln(\frac{I}{P^*}) \quad \text{..........................} (3.22)$$

Where $\omega_i = P_i Q_i / I$. This observation indicates the two specifications being tested. While LA-AIDS model and the transformation of the double log model into a compensated demand contributes to the understanding that the compound model is each unique situation:

Hypothesis: The double log model is correct under the null hypothesis,

$$(1-\lambda)lnQ_i + \lambda\omega_i = \alpha_i + \alpha_{i1}\ln(p_1) + \cdots + \alpha_{iN}\ln(p_n) + \alpha_m \ln\left(\frac{I}{P^*}\right) \quad \text{............} (3.23)$$

The outcome of the estimated λ with the variables on the right side was viewed either as a test of specification or as a test of sufficiency of the demand system linear approximation.

By rearranging the above equation (3.23) we get

$$lnQ_i = \alpha_i + \alpha_{i1}\ln(p_1) + \cdots + \alpha_{iN}\ln(p_n) + \alpha_m \ln\left(\frac{I}{P^*}\right) + \lambda(lnQ_i - \omega_i) \quad \text{..........} (3.24)$$

Now there are two interpretation problems, the first is that the estimation of λ from OLS depends on the scalability of the dependent variable and secondly is that the estimation of λ is associated with the error term so that the result can be biased. We substitute the two possible dependent variables with their expected values in order to solve this issue $\widehat{lnQ_\iota}$ *and* $\widehat{\omega}$ also to avoid the singular model replace other remaining right hand side variables to one predicted value,

$$lnQ_i = \alpha_i + \alpha_{i1}\ln(p_1) + \cdots + \alpha_{iN}\ln(p_n) + \alpha_m \ln\left(\frac{I}{P^*}\right) + \lambda\left(\widehat{lnQ_\iota} - \widehat{\omega_\iota}\right) \quad \text{..} (3.25)$$

$$lnQ_i = \widehat{lnQ_i} + \lambda(\widehat{lnQ_i} - \widehat{\omega_i}) \quad \text{..} (3.26)$$

The prediction error in the double log model closely resemble with the C-test of the Davidson and Mackinnon: $lnQ_i - \widehat{lnQ_i}$ The λ sign is contrary to the normal C-test sign. The second issue was the scaling of the dependent variable so that the OLS estimates move towards minimizing the total amount of the linear combination of two residual vectors of the double log equation (e1) and the share equation (e2):

$$\min e_3' e_3 = \min(1-\lambda)^2 e_1' e_1 + \lambda^2 e_2' e_2 + 2\lambda(1-\lambda) e_1' e_2 \quad \text{........} (3.27)$$

The linear combination of e_1 and e_2 is presented by e_3 so the resulting estimate of λ is given below:

$$\hat{\lambda} = \frac{e_1' e_1 - e_1' e_2}{e_1' e_1 + e_2' e_2 - 2 e_1' e_2} \quad \text{..} (3.28)$$

This above equation shows that $\hat{\lambda}$ depends upon the scaling like e_2 changes while e_1 will not change so that estimated λ will be variant to scaling. To resolve this issue, there is also another modification that instead of using the observed value directly from the share equation, one can use the share model to predict shares and transform each expected share into a ln (Q_i) prediction that results can be compared with results obtained directly from the double log model. So that's the Davidson and Mackinnon C-test in reality. Calculated on the basis of:

$$lnQ_i = \widehat{lnQ_i} + \lambda(\widehat{lnQ_i} - \widetilde{lnQ\iota}) \quad \text{....................................} (3.29)$$

Thus, if the double log model was true, according to the null hypothesis $lnQ_i - \widehat{lnQ_i}$ should not be correlated with the difference of other remaining part like $\widehat{lnQ_i} - \widetilde{lnQ\iota}$ So if the calculated λ is significant as proof against the null hypothesis that the log-log model is accurate (Davidson and MacKinnon, 1981).

3.3.1 Demand projection model

In developing countries like Pakistan policies regarding to household energy demand, energy supply, production and distribution depends on energy demand forecast so demand projections are essential for development. For demand projections, some determined estimates of income elasticity, population growth rate and income growth rate are required. In developing countries for energy demand there are some problems for projection, among which most famous is fast growing population, industrialization and changing preferences etc. In this study, we are concerned with demand forecast of energy at constant rate of income and population. The simple growth model will be used for projecting the energy demand. Several researchers, including Mittal (2008) and Kumar et al. (2009), used this formula.

Using the following growth formula, energy consumption is estimated:

$$D_t = D_0 \times P_t (1 + G \times e)^t \quad \text{..(3.30)}$$

Here

Dt = current year household demand for commodity group and t = 1, 2, 3…….n.

D_0 = base year per capita consumption of commodity group here t = 0.

P_t= current year population[2] (million). Using simple compounding formula, the ADB data set allows us to project the future level of Pakistan's population from 2015 to 2030.

G = GDP per capita growth rate of current year.

e = income elasticity for the particular commodity.

Because it needs less data and parameters, this formula is commonly used to project demand. This model utilizes several assumptions such as steady population growth, no

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[2]$\text{Population}_{\text{future}} = \text{Population}_{\text{present}} * (1+g)^{t}$

Where: g = growth rate of population. t = projected year change in taste and preferences, steady prices, and steady manufacturing technology. This study offers the 2015-2030 energy consumption predictions.

3.4 Energy demand commodities include in analysis

The household energy demand is categorized into two broad groups like fuel demand and other fuels demand and electricity. The expenditure on fuels has been further disaggregated into expenditures on different types of fuel –firewood, kerosene oil, natural gas, cylinder gas, diesel and other-fuels. The other fuels category includes household expenses on coal and other biomass fuels such as dung cakes and crop residue. Using the price of electricity, family income, family size and ownership of electrical appliances explains the household energy demand. In the case of Pakistan, the selected appliances are freezer (fzr), refrigerator (frg), air conditioner (aclor), air cooler (aclor), washing machine (wm) and computer.

We will estimate the following general form of the system equation:

$$Q_i = f(Y_i, P_1, \dots \dots, P_7, NF_i, DAP_i,) \quad \dots\dots\dots (3.31)$$

Where Q_i is energy demand by household for all explanatory variables for i = (1, 2, 3…, 7) here (1 is firewood, 2 is kerosene oil, 3 is natural gas, 4 is cylindrical gas, 5 is diesel 6 is electricity and 7 are other fuels, ,), P_1 = price of firewood, P_2 = price of kerosene oil, P_3 = price of natural gas, P_4 = price of cylindrical gas, P_5 = price of diesel, P_6 = price of electricity and P_7 = price of other fuels. Y is household income, NF is family size and DAP indicates the existence of a specific appliance. For the presence of the specific appliance, the value of each category is 1 and 0 otherwise.

3.4.1 DATA

This study is based on the micro-level data from the 2013-14 Pakistan social and living standards measurement (Social & HIES). The (PSLM) is collected by the Statistics office (PBS) in Pakistan. This data set consists of 17989 households as a nationally representative sample, out of which 387 (2.15 percent) households have not reported expenditures on particular variables which are used in analysis. So the sample of 17602 (97.9 percent) households are used for analysis. Total household expenditure on energy demand are categorized into two broad groups like fuel and other fuels expenditures and electricity. The expenditures on fuel has been further disaggregated into expenditure on different types of fuel –firewood, kerosene oil, natural gas, cylinder gas, diesel and other-fuels. The other fuels category includes household expenses on coal and other biomass fuels such as dung cakes and crop residue, these are the important source of energy. Income data of households is equal to the expenditures of the household and prices data will also be calculated from expenditure. SPSS package is used to arrange the PSLM (2013-14) data set. Data on per capita GDP growth from 2015 to 2030 and data on the complete population and population growth rate for 2015 to 2030 is taken from the key Asia and Pacific 2018 Asian Development Bank (ADB) indicator.

3.5 Econometric modelling

There are two models to estimate the elasticities as double log model and LA-AIDS from which any one model will be selected on the basis of C-test,

- **Double log model**

The compensated double log model for various energy commodities is presented below:

$lnQ_i = \alpha_0 + \alpha_1 lnPF_i + \alpha_2 lnPK_i + \alpha_3 lnPN_i + \alpha_4 lnPC_i + \alpha_5 lnPD_i + \alpha_6 lnPE_i + \alpha_7 lnPOF_i + \alpha_8 NF_i + \alpha_9 DAP_i + \alpha_{10} \ln\left(\frac{Y}{P^*}\right) + \in_i$ ....(3.32)

Where Q_i energy consumption, PF is price of firewood, PK is price of kerosene oil, PN is price of natural gas, PC is price of cylindrical gas, PD is price of diesel, PE is electricity price, POF are prices of other fuels, NF is number of family members, DAP indicates the existence of a specific appliances, Y is income of the household and $P^*$is stone price index define in equation 3.6.

- **Almost Ideal Demand System**

The linear approximation of the almost ideal demand system (LA-AIDS) for various energy commodities is given below:

$\omega_{i,s} = \alpha_i + \alpha_{NF} NF_i + \alpha_{DAP} DAP_i + \alpha_i(lnY_s - lnP_s) + \sum_{j=1}^{7} \alpha_{ij}\, lnp_{j,s} + \epsilon_{i,s}$ ..(3.33)

Where dependent variable $(\omega_{i,s})$ Indicates the spending share of the s-th households of ith energy commodity for $i, j = 1, 2, \ldots\ldots, 7$ (1 is firewood, 2 is kerosene oil, 3 is natural gas, 4 is cylindrical gas, 5 is diesel, 6 is electricity and 7 is other fuels. NF is number of family members and DAP are Appliances), Y_s describes the s-th household's average nominal energy expenditure and lnP_s is the stone price index calculated as follows:

$\ln P_s = \sum_{j=1}^{7} \omega_{i,s} \ln p_{j,s}$ ....(3.34)

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

In this chapter analysis of energy demand and projections of energy demand for Pakistan is given. This chapter is divided into four sections. Section 4.2 explains descriptive statistics of important variables used in this study. Section 4.3 explains the estimated elasticities and their implications. Section 4.4 explains the correct functional form through C-test. Section 4.5 explains the energy demand and its projections for the years 2015 to 2030.

4.2 Descriptive statistics

The descriptive statistics of budget share and prices of Fire wood, Kerosene oil, Natural gas, Cylinder gas, Diesel, Electricity and Other fuels are presented in Table 4.1. It is noted that electricity is a main source of energy consumption having average budget share of 44.94 percent among energy expenditure whereas firewood, other fuels, natural gas, cylinder gas, kerosene oil and Diesel for generator having average budget shares of 24.77, 14.75, 11.19, 2.80, 1.18 and 0.37 respectively, So diesel & petrol for generator has very small budget share percentage because this is very expensive source of energy. Average price for firewood (Rs/kg), kerosene oil (Rs/Ltr), natural gas (Rs/MMBTU), cylinder gas (Rs/kg), diesel (Rs/Ltr), electricity (KWh) and other fuels (Rs/kg) are 8.63, 122.91, 2.56, 138.73, 118.96, 12.27 and 4.55 respectively. The coefficient of variation for prices of various energy commodity group ranges between 3.71 to 234.47 percent, and the largest variation is observed for the price of other fuels category. This is attributed to large differences in price of various other fuel types such as coal, dung cakes, biomass fuels and crop residue. The coefficient of variation is small for kerosene oil and diesel because there are almost same prices for all over the

Pakistan. Household size are ranges from 1 to 47, minimum size is 1 and maximum is 47, Average household size is 7 members.

Table 4. 1: Descriptive statistics

Energy commodity	Mean	Std. Deviation	Coefficient of variation
Budget shares			
Fire wood	24.77	31.17	125.84
Kerosene oil	1.18	5.82	491.94
Natural gas	11.19	17.89	159.89
Cylinder gas	2.80	10.74	383.41
Diesel	0.37	3.39	926.30
Electricity	44.94	27.75	61.75
Other fuels	14.75	24.41	165.46
Price units			
Fire wood	8.63	2.31	26.79
Kerosene oil	122.91	4.56	3.71
Natural gas	2.56	1.37	53.60
Cylinder gas	138.73	10.72	7.73
Diesel	118.96	5.08	4.27
Electricity	12.27	1.57	12.78
Other fuel	4.55	10.67	234.47
House-hold Size	Minimum	Maximum	Mean
	1	47	7

Source: authors calculated based on Pakistan PSLM information (2013-14).

4.3 The uncompensated double-log demand model

The estimated elasticity of the uncompensated double log demand model as shown in equation 3.1 is presented in Table 4.2. The system contains seven energy commodities i.e., Fire wood, Kerosene oil, Natural gas, Cylinder gas, Diesel, electricity and last for other fuels which is estimated by OLS method. Out of seventy seven parameters of seven equations, sixty three parameters are statistically significant (at a level of 5%) whereas one parameters is significant at a level of 10% and plausible for their corresponding variables, but only thirteen parameters are statistically insignificant ($\gamma 23$, $\gamma 26$, $\gamma 27$, $\gamma 29$, $\gamma 31$, $\gamma 35$, $\gamma 39$, $\gamma 41$, $\gamma 43$, $\gamma 49$, $\gamma 54$, $\gamma 58$, $\gamma 79$,) which are not plausible for their corresponding variables.

Table 4. 2: Uncompensated double-log demand model

Parameters	Estimates	Std. Error	P-value	Parameters	Estimates	Std. Error	P-value
α1	7.518	1.103	0.000	**γ45**	-1.201	0.735	0.102
γ11	-1.031	0.024	0.000	**γ46**	-0.169	0.061	0.006
γ12	2.635	0.213	0.000	**γ47**	-0.595	0.179	0.001
γ13	0.493	0.040	0.000	**γ48**	-0.023	0.006	0.000
γ14	-0.178	0.072	0.014	**γ49**	-0.023	0.109	0.830
γ15	-3.308	0.301	0.000	**β4**	0.951	0.038	0.000
γ16	-0.044	0.018	0.017	**α5**	25.834	6.663	0.000
γ17	-1.616	0.077	0.000	**γ51**	-0.724	0.292	0.013
γ18	0.010	0.002	0.000	**γ52**	-2.734	1.421	0.054
γ19	-0.112	0.019	0.000	**γ53**	-0.415	0.082	0.000
β1	0.908	0.014	0.000	**γ54**	-0.754	0.535	0.159
α2	27.806	6.353	0.000	**γ55**	-1.000	0.197	0.000
γ21	-0.147	0.082	0.072	**γ56**	-0.464	0.230	0.044
γ22	-0.949	0.308	0.002	**γ57**	-3.536	0.533	0.000
γ23	0.110	0.147	0.453	**γ58**	0.007	0.010	0.448
γ24	-0.826	0.353	0.020	**γ59**	-0.483	0.214	0.024
γ25	-4.423	1.384	0.001	**β5**	1.170	0.100	0.000
γ26	0.062	0.068	0.358	**α6**	-2.536	0.847	0.003
γ27	-0.331	0.297	0.264	**γ61**	0.078	0.023	0.001
γ28	0.018	0.005	0.001	**γ62**	-1.854	0.167	0.000
γ29	-0.061	0.059	0.301	**γ63**	-0.499	0.017	0.000
β2	0.392	0.048	0.000	**γ64**	0.253	0.064	0.000
α3	3.670	2.088	0.079	**γ65**	0.820	0.160	0.000
γ31	0.064	0.105	0.537	**γ66**	-0.083	0.016	0.000
γ32	0.857	0.455	0.060	**γ67**	1.681	0.058	0.000
γ33	-0.305	0.013	0.000	**γ68**	-0.011	0.002	0.000
γ34	-0.889	0.202	0.000	**γ69**	0.347	0.017	0.000
γ35	-0.001	0.127	0.996	**β6**	0.847	0.011	0.000
γ36	0.786	0.113	0.000	**α7**	30.447	1.988	0.000
γ37	-1.498	0.071	0.000	**γ71**	0.503	0.044	0.000
γ38	0.018	0.002	0.000	**γ72**	-6.883	0.369	0.000
γ39	0.018	0.030	0.541	**γ73**	-0.644	0.077	0.000
β3	0.599	0.013	0.000	**γ74**	0.389	0.150	0.010
α4	17.687	2.974	0.000	**γ75**	0.974	0.519	0.061
γ41	-0.019	0.074	0.794	**γ76**	-0.662	0.020	0.000
γ42	-2.322	0.541	0.000	**γ77**	-1.312	0.139	0.000
γ43	0.224	0.152	0.142	**γ78**	0.013	0.003	0.000
γ44	-1.000	0.081	0.000	**γ79**	-0.024	0.026	0.344
				β7	0.593	0.020	0.000

Source: authors calculated based on Pakistan PSLM information (2013-14).

All the uncompensated own price elasticity statistics have accurate (negative) sign that a commodity's price itself has adverse effect on its unit demand except electricity for which own price electricity is positive as the demand for electricity cannot be reduce due to raise in price. Fourteen elasticities out of forty two uncompensated cross-price elasticities are positive, meaning gross substitute, and the other twenty-eight elasticities are negative, showing complementary consumer goods. All the elasticities of the estimated income are positive. Estimated income elasticity for firewood, kerosene oil, natural gas, cylinder gas, other fuels and electricity are positive and less than one indicates that these products are normal and necessary, but for Diesel is greater than one indicates that the luxury commodity.

4.3.1 The compensated double log demand model

The estimated elasticity of the compensated log-log demand model ~~are~~ is shown in Table 4.3. Where the system of equation for seven energy commodities is estimated by using OLS method. Out of seventy seven parameters of seven equations, sixty one parameters are statistically highly significant (at 5% significance level) and plausible for their corresponding variables, but only sixteen parameters are statistically insignificant ($\gamma19$, $\gamma21$, $\gamma22$, $\gamma23$, $\gamma27$, $\gamma29$, $\beta2$, $\gamma31$, $\gamma35$, $\gamma39$, $\gamma46$, $\gamma56$, $\gamma58$, $\gamma59$, $\gamma75$, $\gamma68$) which are not plausible for their corresponding variables. The fact that the price of a commodity itself has adverse effect on its quantity demand is clarified by all the compensated own price elasticity estimates except electricity. Out of the forty two compensated cross-price elasticities, twenty two are positive, meaning gross substitute, and the other twenty are negative, indicating complementary consumer goods. Estimated income elasticity of firewood, kerosene oil and electricity are positive but less than one indicates that these items are normal and necessary, but for natural gas and other fuels the income elasticity is positive and greater than one shows that these are normal and luxuries items, while income elasticity for cylindrical gas and diesel is negative indicating that these items are inferior.

Table 4. 3: Compensated double-log demand model

Parameters	Estimates	Std. Error	P-value	Parameters	Estimates	Std. Error	P-value
1	3.339	1.081	0.002	**γ45**	-1.443	0.846	0.088
γ11	-0.544	0.022	0.000	**γ46**	-0.081	0.071	0.252
γ12	2.745	0.208	0.000	**γ47**	2.217	0.188	0.000
γ13	0.737	0.039	0.000	**γ48**	0.034	0.006	0.000
γ14	0.170	0.070	0.015	**γ49**	0.405	0.124	0.001
γ15	-3.125	0.295	0.000	**β4**	-0.278	0.028	0.000
γ16	0.143	0.018	0.000	**α5**	28.810	8.016	0.000
γ17	-0.809	0.072	0.000	**γ51**	-1.167	0.346	0.001
γ18	0.011	0.002	0.000	**γ52**	-3.884	1.684	0.021
γ19	-0.020	0.018	0.267	**γ53**	0.167	0.096	0.081
β1	0.814	0.012	0.000	**γ54**	-1.065	0.635	0.093
α2	24.039	6.715	0.000	**γ55**	-0.902	0.234	0.000
γ21	0.056	0.082	0.491	**γ56**	-0.286	0.272	0.293
γ22	-0.383	0.321	0.232	**γ57**	1.891	0.594	0.001
γ23	0.060	0.155	0.699	**γ58**	0.007	0.011	0.534
γ24	-0.736	0.373	0.048	**γ59**	0.260	0.258	0.314
γ25	-4.188	1.461	0.004	**β5**	-0.291	0.101	0.004
γ26	0.184	0.070	0.009	**α6**	-5.370	0.960	0.000
γ27	0.280	0.307	0.362	**γ61**	0.369	0.026	0.000
γ28	0.028	0.006	0.000	**γ62**	-1.807	0.190	0.000
γ29	0.016	0.062	0.796	**γ63**	-0.173	0.019	0.000
β2	0.058	0.043	0.173	**γ64**	0.377	0.073	0.000
α3	5.091	1.428	0.000	**γ65**	0.811	0.181	0.000
γ31	-0.048	0.072	0.504	**γ66**	0.152	0.018	0.000
γ32	0.557	0.312	0.074	**γ67**	3.580	0.057	0.000
γ33	-0.339	0.009	0.000	**γ68**	0.002	0.002	0.334
γ34	-1.242	0.139	0.000	**γ69**	0.480	0.019	0.000
γ35	0.076	0.087	0.378	**β6**	0.404	0.011	0.000
γ36	0.606	0.077	0.000	**α7**	23.002	1.546	0.000
γ37	-1.130	0.037	0.000	**γ71**	0.716	0.034	0.000
γ38	0.007	0.001	0.000	**γ72**	-4.775	0.290	0.000
γ39	-0.015	0.020	0.458	**γ73**	-0.445	0.060	0.000
β3	1.038	0.009	0.000	**γ74**	0.291	0.117	0.013
α4	27.337	3.392	0.000	**γ75**	-0.042	0.405	0.918
γ41	0.362	0.084	0.000	**γ76**	-0.515	0.015	0.000
γ42	-4.716	0.617	0.000	**γ77**	-1.033	0.099	0.000
γ43	0.729	0.174	0.000	**γ78**	-0.013	0.002	0.000
γ44	-0.509	0.091	0.000	**γ79**	-0.043	0.020	0.030
				β7	1.071	0.015	0.000

Source: authors calculated based on Pakistan PSLM information (2013-14).

In Table 4.3 the estimated $\gamma i8$ & $\gamma i9$ are household size and appliances respectively, parameters of household size are positive for all seven energy commodities except other fuels, shows positive impact on the demand of corresponding item. The estimated parameter of appliances for electricity is significant and have positive impact on the demand for electricity.

4.3.2 Estimates of LA-AIDS parameters

Table 4.4 presents the estimated parameters of the LA-AIDS model. Out of total seventy seven parameters of LA-AIDS model for seven commodities, sixty eight parameters are statistically highly significant (at 5% significance level) and Plausible for their respective budget shares, but only nine coefficient are statistically insignificant ($\gamma 24$, $\gamma 32$, $\gamma 33$, $\gamma 37$, $\gamma 42$, $\gamma 53$, $\gamma 56$, $\gamma 59$, $\gamma 74$) which are not plausible for their corresponding budget shares.

4.3.3 Estimated uncompensated and compensated elasticities of LA-AIDS

The uncompensated and compensated own prices elasticities of LA-AIDS are presented in Table 4.5. All the uncompensated and compensated own price elasticity estimates have negative sign, clarifying the fact that a commodity's price itself has adverse effect on its volume demand for all six energy items, while own price elasticity for electricity is positive in both cases indicates that the demand for electricity will not be decline if price of electricity rises. Elasticities estimates results are same for compensated and uncompensated in terms of sign, but magnitude are some different such as the magnitude of uncompensated elasticities of natural gas, firewood and other fuels are higher than compensated which indicates these are normal goods, while the compensated elasticity for cylinder gas and electricity is greater than uncompensated which shows that these are inferior, but for the kerosene oil and diesel the elasticities are same in magnitude which indicates that for these items there is less share of income.

Table 4. 4: LA-AIDS parameters

Parameters	Estimates	Std. Error	P-value	Parameters	Estimates	Std. Error	P-value
α1	-1.964	0.363	0.000	**γ45**	0.230	0.024	0.000
γ11	-0.108	0.010	0.000	**γ46**	0.007	0.002	0.004
γ12	1.294	0.072	0.000	**γ47**	0.206	0.008	0.000
γ13	0.166	0.007	0.000	**γ48**	0.003	0.000	0.000
γ14	-0.076	0.027	0.006	**γ49**	0.035	0.003	0.000
γ15	-0.370	0.068	0.000	**β4**	-0.107	0.001	0.000
γ16	0.040	0.007	0.000	**α5**	0.077	0.046	0.095
γ17	-0.753	0.022	0.000	**γ51**	-0.002	0.001	0.058
γ18	0.008	0.001	0.000	**γ52**	0.093	0.009	0.000
γ19	-0.111	0.007	0.000	**γ53**	0.001	0.001	0.107
β1	0.009	0.004	0.019	**γ54**	0.007	0.003	0.060
α2	0.641	0.030	0.000	**γ55**	-0.128	0.009	0.000
γ21	0.003	0.001	0.000	**γ56**	0.001	0.001	0.426
γ22	-0.117	0.006	0.000	**γ57**	0.032	0.003	0.000
γ23	0.012	0.001	0.000	**γ58**	0.000	0.000	0.001
γ24	0.002	0.002	0.503	**γ59**	0.001	0.001	0.107
γ25	-0.015	0.006	0.009	**β5**	-0.004	0.001	0.000
γ26	0.008	0.001	0.000	**α6**	-1.364	0.278	0.000
γ27	-0.006	0.002	0.002	**γ61**	0.020	0.007	0.008
γ28	0.001	0.000	0.000	**γ62**	-0.477	0.055	0.000
γ29	-0.004	0.001	0.000	**γ63**	-0.239	0.005	0.000
β2	-0.005	0.000	0.000	**γ64**	0.074	0.021	0.000
α3	0.960	0.242	0.000	**γ65**	0.257	0.052	0.000
γ31	0.027	0.006	0.000	**γ66**	-0.033	0.005	0.000
γ32	0.074	0.048	0.120	**γ67**	1.158	0.017	0.000
γ33	0.002	0.005	0.609	**γ68**	-0.005	0.001	0.000
γ34	-0.042	0.018	0.022	**γ69**	0.113	0.005	0.000
γ35	-0.291	0.046	0.000	**β6**	-0.034	0.003	0.000
γ36	0.051	0.005	0.000	**α7**	4.114	0.284	0.000
γ37	-0.022	0.014	0.121	**γ71**	0.034	0.008	0.000
γ38	-0.005	0.000	0.000	**γ72**	-0.905	0.056	0.000
γ39	0.072	0.005	0.000	**γ73**	0.017	0.006	0.002
β3	0.056	0.003	0.000	**γ74**	0.013	0.021	0.539
α4	-1.463	0.128	0.000	**γ75**	0.316	0.053	0.000
γ41	0.026	0.003	0.000	**γ76**	-0.073	0.005	0.000
γ42	0.037	0.025	0.145	**γ77**	-0.614	0.017	0.000
γ43	0.040	0.002	0.000	**γ78**	-0.001	0.001	0.015
γ44	0.023	0.010	0.019	**γ79**	-0.106	0.006	0.000
				β7	0.086	0.003	0.000

Source: authors calculated based on Pakistan PSLM information (2013-14).

Table 4. 5: Own price elasticities of LA-AIDS

Energy commodities	Uncompensated	Compensated
Fire wood	-1.44	-1.19
Kerosene oil	-10.87	-10.87
Natural gas	-1.03	-0.87
Cylinder gas	-0.08	-0.16
Diesel	-35.83	-35.83
Electricity	1.61	2.03
Other fuels	-1.58	-1.35

Source: authors calculated based on Pakistan PSLM information (2013-14).

Table 4.6 presents the uncompensated cross price elasticity of LA-AIDS. Cross price elasticities of Firewood with respect to other six energy commodities are positive signifying gross substitute except for diesel for which firewood is complimentary due to negative elasticity. The uncompensated cross-price elasticity of kerosene oil are positive for firewood, natural gas, Cylinder gas and Diesel and shows substitute while w.r.t electricity and other fuels are negative shows complimentary goods. Natural gas elasticities with respect to other six energy commodities are positive signifying gross substitute except electricity for which natural gas is compliment. Cylinder gas is substitute for Kerosene oil, Diesel, other fuels and for electricity, while cylinder gas is complimentary for Fire-wood and Natural gas. Diesel is complimentary for fire-wood, kerosene oil and for natural gas while Diesel is substitute for other fuels, electricity and cylinder gas. The cross price elasticity of electricity shows that it is compliment for all other energy items except cylinder gas and diesel. Other fuels are substitute for all energy commodities except electricity.

The compensated cross price elasticities of LA-AIDS are presented in Table 4.7. The result of compensated cross price elasticities are same as from uncompensated. All the commodities are same for each other as substitute and compliment except other fuels, other fuels cross price elasticities from uncompensated LA-AIDS shows compliment for electricity, but from Compensated LA-AIDS other fuels are substitute for electricity. Electricity is also substitute for natural gas in compensated cross price elasticities.

Table 4. 6: The uncompensated cross price elasticities of LA-AIDS

Energy Commodities	With respect to the price of						
	Fire wood	Kerosene oil	Natural gas	Cylinder gas	Diesel	Electricity	Other fuels
Fire wood		0.36	0.12	1.89	-0.34	0.06	0.09
Kerosene oil	5.23		0.66	1.36	25.33	-1.06	-6.14
Natural gas	0.67	1.03		1.86	0.53	-0.52	0.05
Cylinder gas	-0.31	0.14	-0.39		1.82	0.17	0.07
Diesel	-1.49	-1.24	-2.60	8.22		0.57	2.14
Electricity	-3.06	-0.27	-0.42	9.06	9.42		-4.43
Other fuels	0.15	0.71	0.38	0.82	0.37	-0.06	

Source: authors calculated based on Pakistan PSLM information (2013-14).

Table 4. 7: The compensated cross price elasticities of LA-AIDS

Energy Commodities	With respect to the price of						
	Fire wood	Kerosene oil	Natural gas	Cylinder gas	Diesel	Electricity	Other fuels
Fire wood		0.50	0.49	1.19	-0.39	0.29	0.48
Kerosene oil	5.24		0.68	1.33	25.33	-1.05	-6.12
Natural gas	0.78	1.09		1.55	0.51	-0.42	0.23
Cylinder gas	-0.28	0.16	-0.35		1.81	0.19	0.12
Diesel	-1.49	-1.24	-2.60	8.21		0.58	2.14
Electricity	-2.59	-0.02	0.25	7.79	9.32		-3.72
Other fuels	0.31	0.79	0.61	0.40	0.34	0.07	

Source: authors calculated based on Pakistan PSLM information (2013-14).

Table 4.8 presents the income elasticity of LA-AIDS and demographic parameters. Estimated income elasticities for Fire wood, natural gas and other fuels are positive and greater than one implies that these item are normal and luxury, while income elasticities for kerosene oil and for electricity are positive and less than one indicates that these are normal and necessity items, but Cylindrical gas and Diesel are negative which indicates that these items are inferior items. Comparing to the findings of (Khan *et al.,* 2015) who reported that all fuel items are necessities for rural household while the negative sign for other fuels, Kerosene oil and fire wood for urban areas shows inferior items. Household size have positive coefficient for Fire wood, Kerosene oil, Cylinder gas and for Diesel which shows that the usage of these product will increase as the size of the family rises, While the size of the family is negative for natural gas, other fuels and for electricity, showing that as the size of the family rises than the consumption of these products decreases (Idrees et al., 2013), the same outcomes were also recorded for the size of the family. The coefficient of appliances are significant and positive for Electricity, Natural gas, and Cylinder gas which indicates that when the number of particular appliances increases than the consumption for these items will increase, while appliances are significant but have negative coefficient for Fire wood, Kerosene oil and for other fuels which shows when appliances increases than consumption for these items will decrease, Hussain & Asad, (2012) also reported the same results for appliances.

Table 4. 8: LA-AIDS income elasticities and demographic parameters

Energy commodities	Income elasticities	HH-SIZE	Appliances
Fire wood	1.04	0.008	-0.111
Kerosene oil	0.57	0.001	-0.004
Natural gas	1.50	-0.005	0.072
Cylinder gas	-2.83	0.003	0.035
Diesel	-0.22	0.000	0.001
Electricity	0.92	-0.005	0.113
Other fuels	1.58	-0.001	-0.106

Source: authors calculated based on Pakistan PSLM information (2013-14).

4.3.4 Comparison of income elasticities from two models

The income elasticities of various energy items from different models are presented in Table 4.9. The income elasticities of all the commodities are almost same except firewood as shown in graph that firewood has positive elasticity but less than one shows normal and necessity in log-log model while in LA-AIDS firewood elasticity is greater than one shows luxury item, (Irfan *et al.,* 2017) also reported that firewood is normal and necessity while (Khan *et al.,* 2015) and (Burney and Akhtar, 1990) reported that firewood is inferior for urban and necessity for rural areas. Kerosene oil is normal and necessity for LA-AIDS and log-log model, (Irfan *et al.,* 2017) and (Burney and Akhtar, 1990) also reported that kerosene oil is normal and necessity, comparatively the magnitude of LA-AIDS elasticity is greater than double log model. Natural Gas is normal and luxury for LA-AIDS and double log model, (Irfan *et al.,* 2017) and (Khan *et al.,* 2015) reported that natural gas is necessity while (Burney and Akhtar, 1990) reported that natural gas is luxury. Cylinder gas and Diesel are inferior for log-log and LA-AIDS, while (Irfan *et al.,* 2017) reported that LPG is necessity which is different from our findings. Electricity income elasticity shows that Electricity is normal and necessity item for household, similar findings are reported in (Burney and Akhtar, 1990) and (Khan *et al.,* 2015). At the end other fuels elasticity results are same for two models as luxury, (Irfan *et al.,* 2017) reported that other fuels are necessities while magnitude was close to unity.

The contradictions in the results of our study with literature are only for cylinder gas, this difference in result of income elasticities is may be due to the less budget share for this commodity as shown in descriptive statistics in table 4.1 like the budget share for cylinder gas is 2.80 percent, very small as compared to firewood, natural gas, other fuels and electricity.

Table 4. 9: The income elasticities from different models

Energy commodities	log-log	LA-AIDS
Fire wood	0.814	1.04
Kerosene oil	0.058	0.57
Natural gas	1.038	1.50
Cylinder gas	-0.278	-2.83
Diesel	-0.291	-0.22
Other fuels	1.071	1.58
Electricity	0.404	0.92

Source: authors calculated based on Pakistan PSLM information (2013-14).

4.3.5 Summary of own price and cross price elasticities

All the compensated own price elasticity estimates of double log model and LA-AIDS for various energy sources (fuels and other fuels) have same negative sign, Explains the fact that the price of a commodity itself has an adverse effect on its demand for quantities, while the own price elasticity of electricity is positive in both models. This indicates that when electricity demand is analyzed along with the demand for other energy sources, it has a positive relation with price, (Idrees et al., 2013) also reported the same findings for electricity. From compensated log-log model all the own price elasticities are price inelastic except electricity (Khan *et al.,* 2015) also reported same findings. But from LA-AIDS model all energy sources are price elastic except natural gas and cylinder gas, while here Diesel is relatively more price elastic as compared to others, (Irfan *et al.,* 2017) reported that natural gas is price elastic which is different from our findings.

Cross price elasticities from double-log model for Firewood is positive with respect to all the sources of energy, indicates that fire wood is substitute excluding natural gas and diesel where the sign is negative shows compliment for household (Khan *et al.,* 2015) also reported similar findings. Kerosene oil is substitute for fire wood and natural gas, while kerosene oil is compliment for cylinder gas, diesel, other fuels and for electricity (Irfan *et al.,* 2017) also reported the similar findings. Natural gas is substitute for all other sources except other fuels and electricity, (Khan *et al.,* 2015) also reported that natural gas is substitute for kerosene oil and compliment for electricity and for other fuels. (Irfan *et al.,* 2017). Cylinder gas or LPG is substitute for fire wood, other fuels and electricity while cylinder gas is compliment for kerosene oil, natural gas and diesel, (Irfan *et al.,* 2017) also reported that LPG is substitute for firewood and natural gas and compliment for kerosene oil. Diesel is compliment for all sources of energy except natural gas and electricity for which diesel is substitute. Electricity is compliment for firewood, natural gas and other fuels while electricity is substitute for kerosene oil, cylinder gas and diesel, (Khan *et al.,* 2015) also reported the same findings. Other fuels are substitute for all type of energy sources except cylinder gas and diesel for which other fuels are complement, Burney & Akhtar, (1990) reported that other fuels are compliment for all type of energy sources while (Irfan *et al.,* 2017) reported that other fuels are substitute for fire wood, kerosene oil and both type of gases.

Cross price elasticities from LA-AIDS shows that firewood is substitute for all type of energy sources except Diesel for which firewood is compliment, (Irfan *et al.,* 2017) also reported that fire wood is substitute for all rest of energy sources. Kerosene oil is substitute for all energy sources except other fuels and electricity for which kerosene oil is compliment, Burney & Akhtar, (1990) also reported that kerosene oil is compliment for electricity and other fuels while (Irfan *et al.,* 2017) reported that kerosene oil is substitute for firewood. Natural gas is substitute for all other energy sources which is also reported by (Irfan *et al.,* 2017), but natural gas is compliment for electricity which is also reported by (Khan *et al.,* 2015). Cylinder gas is substitute for all energy sources except natural gas and firewood for which cylinder gas is compliment. Diesel is compliment for kerosene oil, firewood and natural gas while Diesel is substitute for cylinder gas, other fuels and electricity, which is not reported by (Irfan *et al.,* 2017) and (Khan *et al.,* 2015). Electricity is compliment for firewood, kerosene oil and other fuels while electricity is substitute for natural gas, cylinder gas and diesel, (Khan *et al.,* 2015) also reported the same findings, while Burney & Akhtar, (1990) reported that electricity is compliment for both type of gases. Other fuels are substitute for all energy sources, (Irfan *et al.,* 2017) also reported that other fuels are substitute for natural gas, cylinder gas, firewood, and kerosene oil.

4.4 Correct functional form test for energy modeling

The functional form test i.e., C-test which is discussed in section 3.3 is applied to all the items of energy, Firewood, Kerosene oil, Natural gas, cylindrical gas, Diesel, electricity and Other fuels The compensated log-log model for all seven energy equations is tested in contradiction of a model which have same independent or similar right hand side variables, but with different dependent variables which are budget share for various energy commodities also known as linear approximation of almost ideal demand system (LA-AIDS).

The functional form, C-test results are presented in Table 4.10. The significance of λ parameter in equation (3.30) will lead to reject the model under null-hypothesis. The lambda is significant for the log-log model for all energy equations excluding kerosene oil and diesel for which lambda is insignificant, so for kerosene oil and diesel we cannot reject our null that double log model is correct, while null hypothesis that double log model is correct is rejected for Firewood, Natural gas, cylindrical gas, other fuels and electricity. For LA-AIDS energy equations the lambda is statistically significant for kerosene oil, diesel and cylinder gas, while lambda is insignificant for the rest of energy commodities. So we cannot reject our null that LA-AIDS model is correct for firewood, natural gas, other fuels and electricity, while null that LA-AIDS is correct is rejected for kerosene oil and diesel for which double log model was not rejected, but for cylinder gas results are inconclusive, from the findings of base paper (Alston *et al*., 2002) it is indicated that for inconclusive results they prefer LA-AIDS. The C-test recommends that the LA-AIDS model is not rejected for the main energy sources, as we know that budget shares for firewood, natural gas, other fuels and electricity are 96 percent for which C-test recommends the LA-AIDS. So we prefer the LA-AIDS model over double log model. Also the results of LA-AIDS model are according to economic theory and similar to the findings of (Irfan *et al.,* 2017) which allows to prefer LA-AIDS over double log model.

Table 4. 10: C-Test for correct functional

C-Test		Estimates	Std. Error	P-value
H_0: The log-log model is correct				
	Fire wood	-0.092	0.008	0.000*
	Kerosene oil	-0.018	0.012	0.145
	Natural gas	0.031	0.004	0.000*
	Cylinder gas	-0.168	0.016	0.000*
	Diesel	-0.015	0.019	0.419
	Electricity	-0.799	0.012	0.000*
	Other fuels	-1.145	0.004	0.000*
H_0: The linear approximation of almost ideal demand system is correct				
	Fire wood	0.014	0.009	0.141
	Kerosene oil	0.027	0.008	0.001*
	Natural gas	-0.015	0.011	0.176
	Cylinder gas	0.203	0.006	0.000*
	Diesel	0.011	0.002	0.000*
	Electricity	0.002	0.003	0.513
	Other fuels	-0.004	0.011	0.734

Source: authors calculated based on Pakistan PSLM information (2013-14). * Shows that null hypothesis is rejected that model is correct at 5% level of significance.

4.5 Energy Demand Projections in Pakistan

Energy demand is estimated from 2015 to 2030 by using 2014 as the base year. Different energy commodity groups such as firewood, kerosene oil, natural gas, cylindrical gas, diesel, electricity and other fuels are projected.

4.5.1 Total household energy consumption in Pakistan

The household energy consumptions for the year 2014 are presented in Table 4.11. Monthly values of consumption are reported in data set, which enable us to calculate the annual consumption and per capita consumption of the households which are shown in table 4.11. Per capita household energy in the year 2014 is used as base year for energy demand projections. All the consumption data set is taken from PSLM (2013-14). The total per capita household energy demand for fuels is observed as 243.02 kg/year which is higher than other fuels 100.57 kg/year. From fuels per capita consumption of natural gas (143.9) kg/year is higher than Firewood (97.6) kg/year, Per capita energy consumption of diesel/petrol for generator is lowest (0.21) Ltr/year than kerosene oil 0.23 kg/year and cylinder gas 1.01 kg/year. It can be observed that per capita energy consumption for electricity (132.02 KWh) which is also higher than other fuels, because from descriptive statistics we know that 45 percent budget shares are only for electricity, so the annual demand for electricity is 15416890.32 (KWh).

4.5.2 Population Projections

The total present population and projections of population are presented in Table 4.12. Asian Development Bank (ADB) key indicator for the Asia and Pacific 2018 data set shows that total population of Pakistan for the year 2014 was 188.02 million and for 2017 was 207.77 million. The average growth rate of the overall population from 2001 to 2017 was 2.36, according to ADB information, this average growth rate (2.36) is used to forecast the future population level. Based on this data, with the support of simple compound formula, we estimated the population of Pakistan from 2015 to 2030. The country's total population is anticipated to grow from 207.77 million in 2017 to 222.80 million by 2020, 250.32 million by 2025 and 281.22 million by 2030.

Table 4. 11: Total per capita household consumption in (2013-14)

Energy commodities	Monthly kg/Ltr	Annual kg/Ltr	Per Capita Consumption
Fire wood	949835.25	11398023.00	97.60
Kerosene oil	2213.41	26560.92	0.23
Natural gas	1401100.00	16813200.00	143.97
Cylinder gas	9787.83	117453.96	1.01
Diesel	2023.24	24278.88	0.21
Total fuels	-	-	243.02
Other fuels	978716.22	11744594.64	100.57
Electricity	1284740.86*	15416890.32*	132.02

Source: authors calculated based on Pakistan PSLM information (2013-14). * Shows that Electricity is in KWh.

Table 4. 12: Total projected population from 2018 to 2030

Years	Total Population	Years	Total Population
2014*	188.02	2023	238.92
2015*	191.71	2024	244.55
2016*	195.39	2025	250.32
2017*	207.77	2026	256.21
2018	212.66	2027	262.25
2019	217.68	2028	268.43
2020	222.80	2029	274.75
2021	228.05	2030	281.22
2022	233.43		

* Shows that total population for that year is reported in ADB data set, and next years are projected years.

4.5.3 Income Growth rates

The projected income/GDP growth rate are presented in Table 4.13. The projected data set is available from the key Asia and Pacific 2018 Asian Development Bank (ADB) indicator. The country's income growth rate is anticipated to rise from 3.11 in 2014 to 3.71 in 2019, 3.90 in 2025 and 4.01 in 2030.

Table 4. 13: The projected Income Growth rates

Years	GDP growth rate	Years	GDP growth rate
2014	3.11	2023	3.91
2015	3.20	2024	3.93
2016	4.01	2025	3.90
2017	4.19	2026	3.92
2018	4.05	2027	3.94
2019	3.71	2028	3.96
2020	3.97	2029	3.98
2021	3.98	2030	4.01
2022	3.99		

Source: Asian development bank key indicator for the Asia and pacific 2018.

4.5.4 Income elasticities from LA-AIDS model

The income elasticities of various energy commodities from LA-AIDS model are presented in Table 4.14. As from the results of C-test we have selected the linear approximation of almost ideal demand system (LA-AIDS) over double log model, so the income elasticities from LA-AIDS model are used for projections. It is expected that elasticities with positive sign (normal) will increase the future demand and elasticities with negative sign (inferior) will decrease the future level of demand for that energy item. Firewood, kerosene oil, natural gas, other fuels and electricity has positive coefficient, so the consumption demand for these items should be increase, while consumption demand for cylinder gas and diesel is expected to decrease, as the elasticities of LA-AIDS for these items indicates that the demand will be decrease in future, this contradiction is may due to small budget shares for these items.

Table 4. 14: The income elasticities from LA-AIDS models

Energy commodities	Income elasticities
Fire wood	1.04
Kerosene oil	0.57
Natural gas	1.50
Cylinder gas	-2.83
Diesel	-0.22
Electricity	0.92
Other fuels	1.58

Source: authors calculated based on Pakistan PSLM information (2013-14).

4.5.5 Future energy demand for Pakistan

Energy demand based on various items is estimated from LA-AIDS model, to project the future level demand energy we need income elasticity which are also calculated from the models, are presented in above Table 4.14. Per capita household consumption, total projected population and projected GDP growth rate is also shown above which will be used for projections.

4.5.6 Projections based on income elasticities from LA-AIDS

The projections of per capita energy demand on the basis of LA-AIDS model are presented in Table 4.15. Projections are made under the assumption that there is constant or average growth in population, constant prices, no change in taste and preferences, and constant technology of production. Projections results of LA-AIDS for energy demand shows that the per capita demand of natural gas is expected to rise from 143.97 kg/year in 2014 to 365.87 kg/year in 2030 which is relatively higher demand than other fuels 100.57 kg/year in 2014 to 269.32 kg/year in 2030 and firewood 97.60 kg/year in 2014 187.48 kg/year in 2030. Kerosene oil has very small positive income elasticity due to which the expected rise in demand is very small almost unchanged, as it expected to rise from 0.23 Ltr/year in 2014 to 0.33 Ltr/year in

2030. Diesel and cylinder gas has negative elasticity and the per capita demand for these two is expected to decline from 2014 to 2030 as shown in table but that decline in per capita demand is almost unchanged. The per capita demand for electricity at household hold level is expected to rise from 132.02 KWh/year in 2014 to 236.32 KWh/year in 2030. So the overall energy demand for all main sources of energy is expected to double in next decades especially for natural gas, firewood, other fuels and electricity.

Table 4. 15: Per capita energy demand projections

Years	Fire wood	Kerosene oil	Natural gas	Cylinder gas	Diesel	Electricity	Other fuels
2014	97.60	0.23	143.97	1.01	0.21	132.02	100.57
2018	115.08	0.25	182.16	0.62	0.20	152.91	128.94
2022	135.05	0.27	228.97	0.39	0.19	176.37	164.17
2026	157.60	0.30	285.53	0.24	0.19	202.42	207.28
2030	187.48	0.33	365.87	0.15	0.18	236.32	269.32

Source: authors calculated based on Pakistan PSLM information (2013-14).

The total (kg/year) demand from two different models (double log model and LA-AIDS) and their per capita energy demand graphs for various energy items are presented in the appendix.

CHAPTER 5

CONCLUSION AND POLICY IMPLICATIONS

5.1 Introduction

The chapter is about the findings, recommendation and policy implication of the empirical analysis. The chapter is divided into three sections. Section 5.2 deals with the major findings of the study. The policy implication and recommendations are given in section 5.3. At the end limitations of the study are discussed in section 5.4.

5.2 Major findings of the study

This study was tries to choose the correct functional form in energy modeling, to analyze the demand of energy for Pakistan and projections of future energy demand for various energy items. This analysis was based on the 2013-14 micro-level information from the measurement of social and living standards (Social & HIES) in Pakistan. The important contribution of the study is that we are selecting correct functional between two alternatives by using C-test. Two alternative models, double log model and linear approximation of the almost ideal demand system are tested that double log model is correct under the null hypothesis for which the results of C-test indicates that lambda is statistically significant for all types of fuels and other fuels (except kerosene oil and diesel) which is against our null hypothesis, while lambda is insignificant for kerosene oil and diesel in the favor of null hypothesis.

C-test under the null hypothesis that LA-AIDS is correct, indicates that lambda is statistically significant just for kerosene oil, diesel and cylinder for which double log model was correct. While C-test recommends that LA-AIDS model is correct for all other main energy items like firewood, natural gas, other fuels and electricity. So the C-test allows to prefer the LA-AIDS over double log model also due to more consistent results with literature we prefer LA-AIDS model over double log model.

Major findings of the study for various energy items are given below:

1. All the uncompensated and compensated own price elasticities have accurate (negative) sign which shows that the price of a commodity itself has adverse effect on its demand for quantities from both models as double log and LA-AIDS, except electricity for which own price elasticity is positive, which shows favorable effect on its demand, as we prefer the LA-AIDS model which indicates that all the own price elasticities are price elastic as less than negative unity (ε_{ii}) excluding natural gas and cylinder gas.
2. The income elasticities of all the commodities are almost same from both the model except firewood which is normal and necessity in log-log model while in LA-AIDS firewood is luxury item. Kerosene oil and electricity are normal and necessity for LA-AIDS and log-log model, Natural Gas and other fuels are normal and luxury for LA-AIDS and double log model, Cylinder gas and Diesel are inferior for log-log and LA-AIDS.
3. The energy demand estimated of this empirical analysis suggests that if the population grows by 2.36 percent per year than the household per capita demand for energy products will rise over the next decade by maintaining prices constant. It is indicated that demand from households is driven by population growth and income growth.

The projections of energy demand for various items are made by using the income elasticities from LA-AIDS model maintaining prices constant when the population is increasing by 2.36 percent per year compared to household per capita demand for significant energy products is nearly the same (expected to rise for decades to come).

5.3 Policy implications and recommendations

For policy applications, the empirical findings obtained from this research are very important. The estimated elasticity of own prices, cross-prices and income in terms of spending (income), family size and equipment is particularly important to producers and policy makers in making investment and incentive choices. The significant part of the budget for families is for electricity, natural gas, firewood and other fuels, smaller budget shares are set down to other items such as kerosene oil, cylinder gas and diesel. Fire wood is a solid fuel and the cutting process of wood for energy purpose will decrease the resources of forest and therefore the diminishing of forestry will leads to plentiful environmental harms. So this is important for governments to reflect policies that boost the use of other types of clean fuels like natural gas and cylinder gas etc. and there should be disincentive to the use of these solid fuels as firewood. The administration should also decline the use of these solid fuels at household level to control the numerous environmental and health problems. Due to no proper market of these solid fuels (firewood and other fuels) the authorities has restricted power to control the price of these solid fuels. So there should be taxing policy for these solid fuels to tackle this issue, in case if government impose tax on firewood which results the increase in the price of these solid fuels due to which the quantity demanded of firewood will be reduced. Interesting, when there is tax on firewood than it would increase demand quantity of cylinder gas (which is expected to decline in next decades) more than as compared to natural gas. Similarly if government subsidies on clean fuels (natural gas, cylinder gas and electricity) for households than it would also increase the demand for these clean fuels and would reduce the consumption of solid fuels. There positive relationship exists between energy demand and household size. The predictions based on assumptions for different energy products indicate the excessive liability for producing electricity and natural gas for national demand imposed on the production industry, because there is expected to high rise in demand for electricity and natural gas in next decades. Energy policy is most important and one of the major government policies because it demonstrates national independency, sustainable economy and society.

The results of the study show that energy prices, household income and household size all play an important role in determining the demand for energy. Therefore, demand side policies can play a vital role in decreasing the gap between energy demand and supply. Some determinants, like energy prices and household size, can be influenced by government policies. Energy prices, for example, can be influenced through the system of taxation, and household size through family planning programs. 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. Recently, it has become standard practice in different European countries for government to educate households to decrease electricity consumption in order to conserve resources and avoid waste.

5.4 Limitations of the study

The projection of per capita energy demand are based on some assumptions, such as constant or average growth in population, constant prices, no change in taste and preferences, and constant technology of production. If there is any change in these parameters than it would change the projections for energy demand. For example, a huge increase in the prices of electricity in terms of taxes, would reduce the quantity demand for household etc.

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APPENDIX

Appendix Table 1: *Total energy demand (Kg) projections from LA-AIDS model*

Year	Fire wood	Kerosene oil	Natural gas	Cylinder gas	Diesel	Electricity	Other fuels
2014	11398.02	26.56	16813.20	117.45	24.28	15416.89	11744.59
2015	19332.96	44.40	28922.71	175.33	39.57	26057.15	20256.99
2016	20690.48	46.50	31605.98	154.42	39.90	27740.44	22222.82
2017	23042.40	50.73	35900.69	143.02	42.00	30740.18	25335.92
2018	24472.75	53.00	38739.77	131.38	42.64	32518.11	27421.07
2019	25668.61	54.98	41068.21	125.58	43.42	34016.22	29127.64
2020	27704.28	57.96	45338.14	109.57	43.93	36504.98	32292.15
2021	29549.10	60.69	49218.24	99.29	44.56	38763.04	35171.80
2022	31523.66	63.57	53446.95	89.90	45.19	41168.83	38320.75
2023	33355.73	66.27	57369.15	83.57	45.92	43404.85	41243.65
2024	35599.34	69.42	62334.61	75.57	46.58	46115.72	44963.95
2025	37819.79	72.54	67290.59	69.35	47.29	48795.21	48684.63
2026	40379.85	76.01	73156.33	62.63	47.95	51861.31	53107.92
2027	43111.72	79.64	79529.51	56.57	48.63	55118.40	57930.12
2028	46065.44	83.49	86556.41	50.96	49.31	58622.15	63266.10
2029	49261.46	87.55	94312.43	45.79	49.99	62393.85	69177.29
2030	52725.38	91.87	102890.95	41.03	50.67	66460.24	75739.77

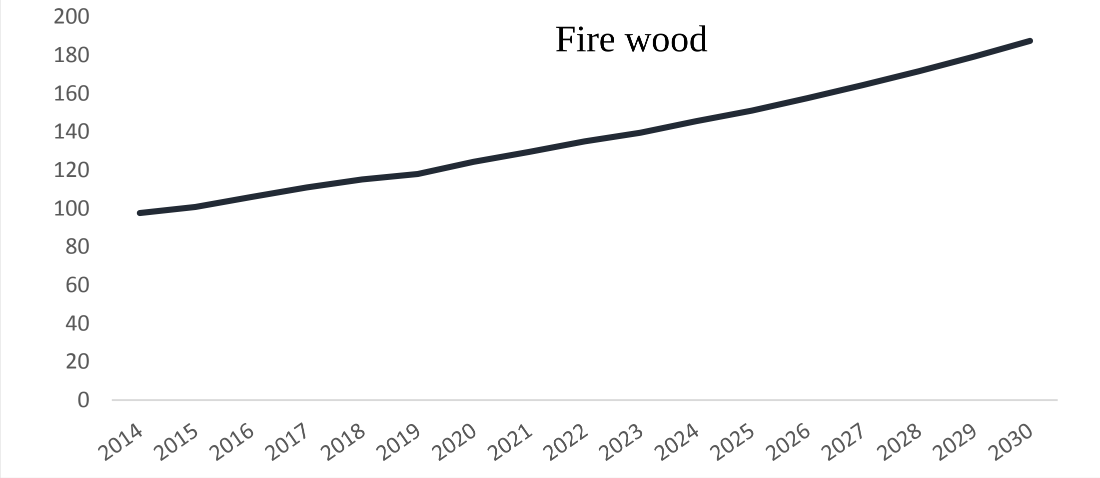
Source: authors calculated based on Pakistan PSLM information (2013-14).

Appendix Table 2: *Total energy demand (Kg) projections from double log model*

Year	Fire wood	Kerosene oil	Natural gas	Cylinder gas	Diesel	Electricity	Other fuels
2014	11398.02	26.56	16813.20	117.45	24.28	15416.89	11744.59
2015	19198.90	43.68	28517.79	191.10	39.49	25635.92	19940.78
2016	20335.58	44.65	30519.88	192.16	39.68	26636.59	21372.74
2017	22426.48	47.60	33988.74	201.75	41.64	28845.55	23835.74
2018	23632.27	48.83	36098.27	204.42	42.17	29957.24	25343.98
2019	24657.63	50.05	37861.98	207.86	42.86	30957.09	26602.50
2020	26316.27	51.38	40864.13	209.66	43.21	32357.00	28758.56
2021	27824.45	52.72	43584.83	212.18	43.70	33660.94	30712.17
2022	29424.15	54.09	46496.83	214.72	44.20	35020.49	32805.87
2023	30914.79	55.47	49198.70	217.79	44.82	36316.13	34747.84
2024	32702.83	56.91	52507.43	220.37	45.32	37789.12	37132.44
2025	34468.85	58.37	55781.99	223.27	45.90	39249.96	39493.46
2026	36474.01	59.89	59557.32	225.89	46.41	40848.47	42221.16
2027	38594.78	61.45	63585.99	228.55	46.93	42511.50	45135.66
2028	40864.83	63.06	67941.75	231.18	47.45	44256.43	48291.31
2029	43296.18	64.70	72654.78	233.79	47.95	46087.88	51710.77
2030	45903.99	66.40	77762.80	236.37	48.46	48011.89	55422.32

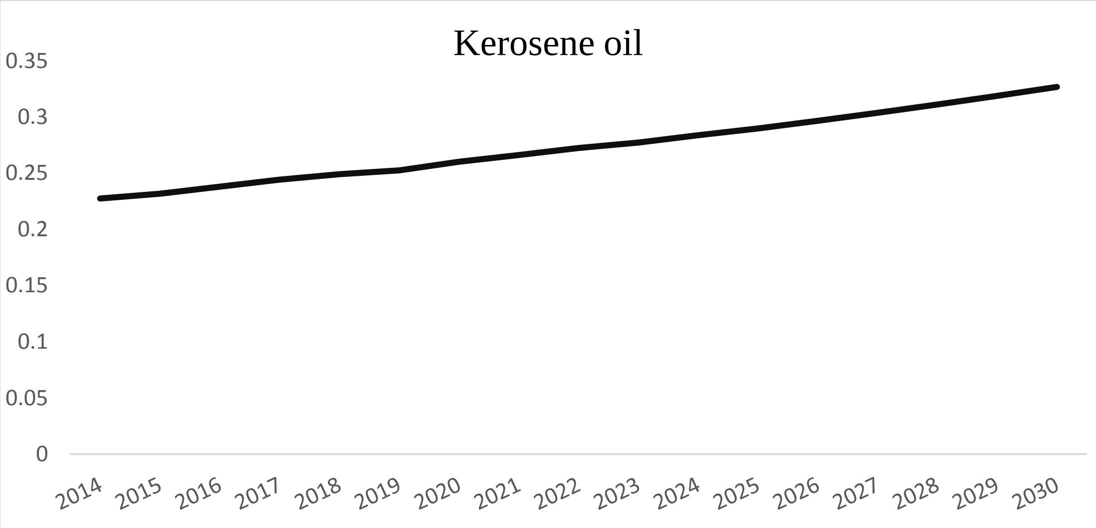
Source: authors calculated based on Pakistan PSLM information (2013-14).

Appendix Figure 1: *Projections of per capita demand for firewood*



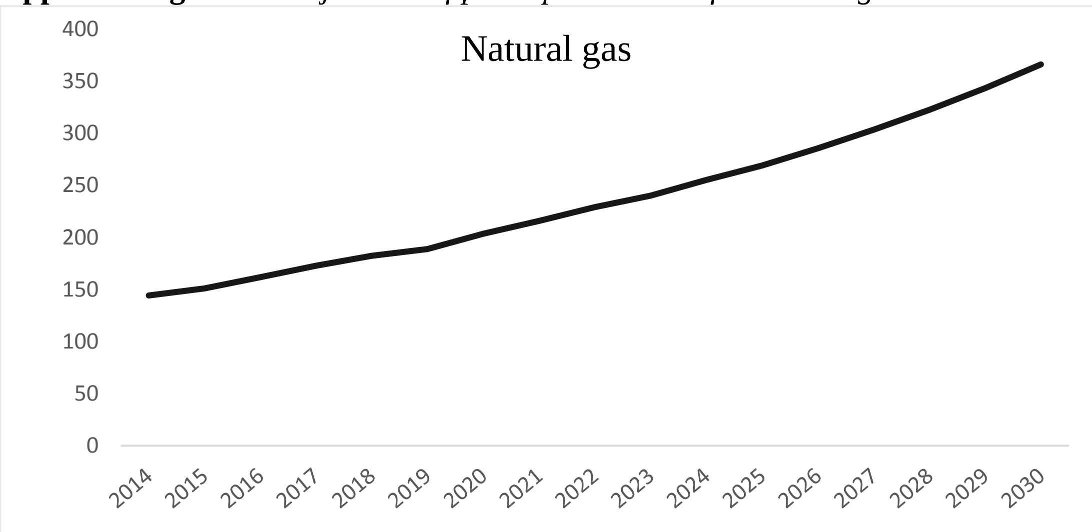
Source: authors calculated based on Pakistan PSLM information (2013-14).

Appendix Figure 2: *Projections of per capita demand for kerosene oil*



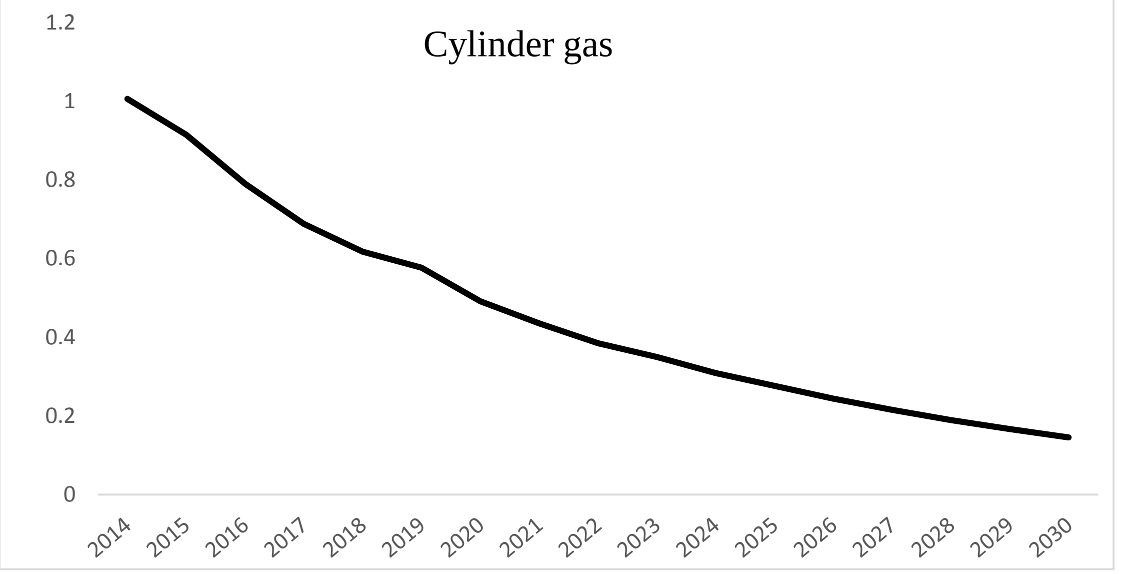
Source: authors calculated based on Pakistan PSLM information (2013-14).

Appendix Figure 3: *Projections of per capita demand for natural gas*



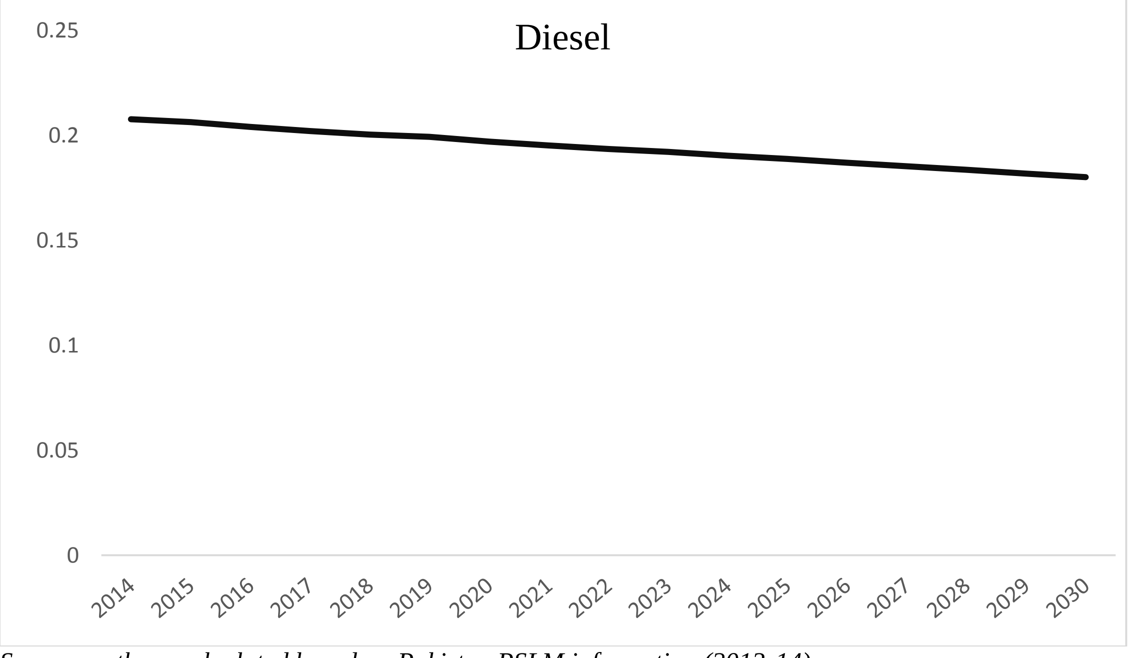
Source: authors calculated based on Pakistan PSLM information (2013-

Appendix Figure 4: *Projections of per capita demand for cylinder gas*



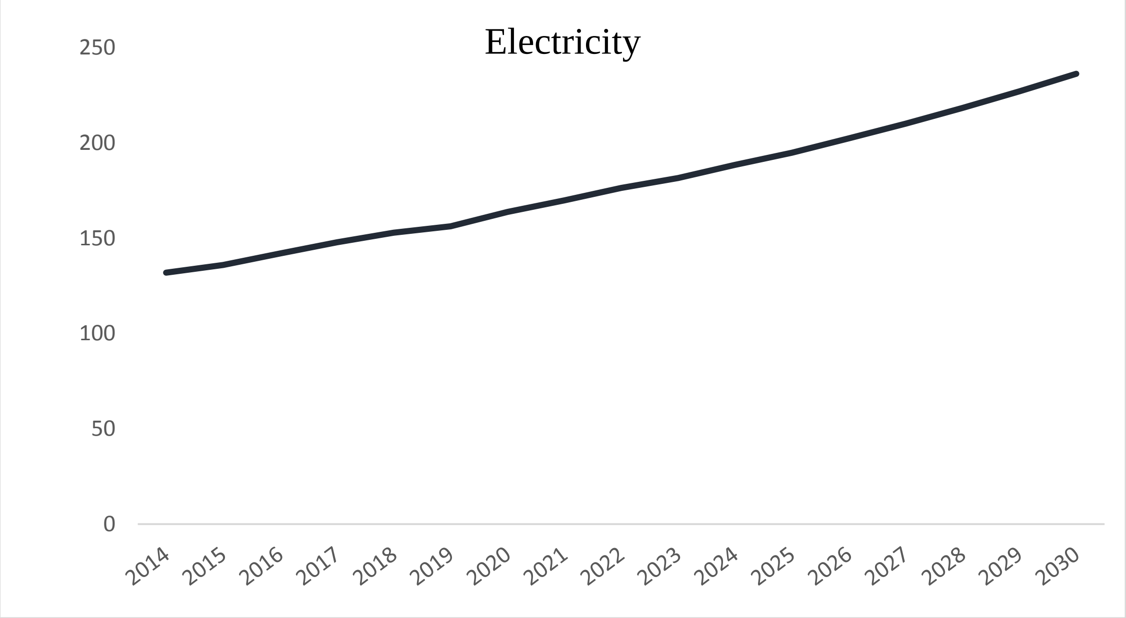
Source: authors calculated based on Pakistan PSLM information (2013-14).

Appendix Figure 5: *Projections of per capita demand for diesel*



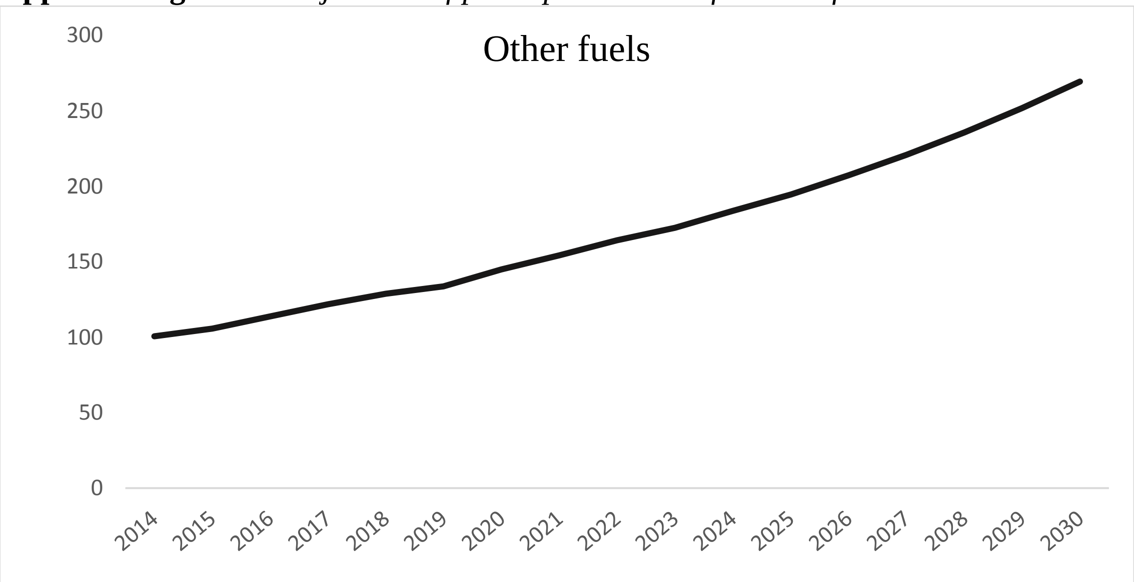
Source: authors calculated based on Pakistan PSLM information (2013-14).

Appendix Figure 6: *Projections of per capita demand for electricity*



Source: authors calculated based on Pakistan PSLM information (2013-14).

Appendix Figure 7: *Projections of per capita demand for other fuels*



Source: authors calculated based on Pakistan PSLM information (2013-14).