ENERGY DEMAND AND CONSUMER WELFARE IN PAKISTAN

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Dedicated to my beloved mother, whose prayers for me, were what sustained me thus far

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Rubina Ilyas

Abstract

Pakistan meets nearly one-third of its energy needs through imported energy resources i.e. coal, oil and Liquefied Natural Gas (LNG). Despite significant investments in energy infrastructure (especially in power generation projects), Pakistan continues to be energy insecure. This dissertation aims to examine Pakistan's energy demand structure utilizing macro and micro-level data sets. In this regard, three research themes have been investigated. The first essay comprises of an analysis of the demand elasticities of energy sources for different economic groups over a period of 35 years. In addition this essay also examines the possibility of substitution between within energy products as well as between energy and non-energy input factors using a trans-log production function. The second essay focuses on the estimation of the intertemporal patterns of household expenditure for three main energy sources. The price and income elasticities for these energy sources have been computed using Extended Linear Expenditure System methodology to examine the responsiveness of households to price and income changes. The third essay employs the price gap approach in order to assess the potential impact of subsidy removal on electricity consumption by economic sectors. Moreover, it carries out a benefit incidence analysis to determine how successful the policy reform has been in targeting the poor HHs.

The results indicate that increasing the energy prices alone may not be effective for energy conservation purposes. The positive substitution elasticity of oil by gas in Pakistan implies that Pakistan can shift its load of power generation from costly oil to natural gas. Moreover, it has been observed that potential energy can be saved by charging tariffs equal to the supply cost of electricity in case of the residential sector.. The government may like to reduce subsidy across the consumption quintiles excepting first and second (the poorest HHs) to improve the country's budgetary situation without adversely affecting the relatively affluent classes. The benefit incidence analysis shows that charging higher price of energy (electricity) for consumers having a high consumption will reduce the leakage to the rich and it will be possible to improve the benefit incidence for the poor who will suffer if the price of electricity is raised uniformly for all the users.

JEL Classifications: *C02, C31, C63*

Keywords: *Energy demand; Energy prices; Demand elasticities*

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LIST OF ABBREVIATIONS

APTMA	All-Pakistan Textile Millers Association
CNG	Compressed Natural Gas
DISCO	Distribution Company
GWh	Gigawatt hour
HHs	Households
IBT	Incremental Block Tariff
ICRG	International Country Risk Guide
IEA	International Energy Agency
IMF	International Monetary Fund
LPG	Liquefied Petroleum Gas
MMt	Million Metric Tons
MoWP	Ministry of Water and Power
MW	Megawatt
NBP	National Bank of Pakistan
NEPRA	National Electric Power Regulatory Authority
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
PSLM	Pakistan Social and Living Standards Measurement
T&D	Transmission and Distribution
TDS	Tariff Differential Subsidy

INTRODUCTION

One of the most pertinent concerns that many countries are facing nowadays is the ever increasing consumption of energy. With the development of societies and technological blooming the energy problems are becoming inevitable. During the past few decades, Pakistan also went through severe power and gas shortage. Unable to meet its energy demand with the existing generating capacity, Pakistan has to pay heavily for the import of energy (Malik et al., 2020). The energy needs are expected to increase three folds by 2050 while the supplies are not very inspiring. Currently 38% of the country's energy requirements are fulfilled by imported energy (Pakistan Economic Survey, 2020). The existing energy mix of Pakistan is highly reliant on gas, oil and expensive fuels instead of coal and hydel. The dependence on imported oil which is about 85% of the total supply is not only making the energy mix unfavorable but is also adding to the fiscal burden. Besides causing a drainage of its foreign exchange reserves, it makes the economy vulnerable to international energy price shocks which raises the risk of inflation (Yaqoob et al, 2021). Inflationary pressures have adverse implications for the economy's exports which further shrinks the capacity to purchase energy imports.

The import of petroleum products contributed to the import bill by 17% in 2019. As international oil prices remained high in 2018, the cost of imported energy escalated by 25% ($13.3 billion) raising the contribution of imported energy to 37% in the import bill (State bank, 2019). During 2019, Pakistan imported 6.6 million tons of oil from the international market which worth a valuing of 3.4 billion USD. Successive energy policies have focused on the expansion and diversification of the energy system through installation of new energy projects, yet the production capacity fails to fulfill the energy needs. After a long period of power generation shortages, the power generation capacity has become more than sufficient to meet the total demand in the country. The power generation capacity of Pakistan was increased by 13,298MW during the phase of 2016-21 (NEPRA, 2020). However, in order to utilize this increased capacity there is a need of efficient T& D network to transmit electricity to the load centers. There are a number of constraints in the existing T & D network of NTDC which cause underutilization of the efficient plants. Another impediment that causes successful transmission of electricity is the policy of power outages adopted by DISCOs despite the availability of sufficient generating capacity (State of Industry Report 2020, NEPRA). Due to these inefficiencies in the power system, consumers are still facing power outages in addition to the high tariffs of electricity (Afia, 2020). There is a persistent shortfall in the country during peak hours. Investments in T & D infrastructure are far less than the investments made to increase generation capacity.

In addition to electricity crisis, Pakistan is also facing gas crisis despite being sufficient in gas supply. According to some estimates the country has entered the deficiency state after 2006 (Malik et al., 2020). Before 2006, the local resources have fulfilled the demand of the domestic as well as the commercial and industrial consumers with an ample supply. The growth rate of consumption increased rapidly during 2015-16 while the growth rate of production was 1.2%. The shortfalls of gas supply have leaded to gas load shedding and supply cuts especially in the winter seasons. The severity of this shortfall can be assessed by the decision of the government implementing load shedding of two days per week on CNG stations and industries since November 2009 to March 2010 (Hhan et al., 2012). If this trend of gas consumption continues, the supply and demand gap will rise by 80 time till 2030 (Hathway and Kugelmn, 2012). Pakistan’s dependence on imported energy (oil, coal and LNG) is expected to increase further with the depletion of local gas reserves (Mahmood et al., 2014). The gas production has been projected to fall from 4 billion cubic feet per day currently to about 2 billion cubic feet per day by 2025. While, its demand is expected to increase by 1.5 billion cubic feet per day which will have serious consequences in terms of energy imports (Malik et al., 2020). Compressed Natural Gas (CNG), which is used as an alternate for fuels (petrol and diesel) is also in deficit. The estimated increase in the supply shortage has increased by 38% amounting to 220 M cubic feet in Punjab and Khyber Pakhtunkhwa (Dost, 2016). While, Pakistan has become the world leading CNG user with more than 3 million natural gas vehicles on the roads (Pakistan Economic Survey, 2017). Considering the depleting gas reserves, importation of gas has become necessary. Resultantly, the government of Pakistan has initiated importing projects of gas from Iran (IP Pipeline) and Turkmenistan (Turkmenistan–Afghanistan–Pakistan–India -TAPI Pipeline), and LNG from Qatar (Raza et al., 2019).

In view of the current challenges, this dissertation aims to analyze Pakistan's energy demand structure, by conducting three empirical investigations. The first essay analyzes the energy consumption of Pakistan by determining the important factors that affect the demand of different sources (Electricity, natural gas and petroleum products) of energy by various economic groups (i.e., domestic, industry, commercial and agricultural sectors). Setting optimal energy policies has become a serious challenge for the government. In order to examine the impact of increases or decreases in the prices of energy sources, accurate estimates of the price and income elasticities of energy sources are imperative (Irfan et al., 2020). However, most studies have only estimated the demand elasticities of electricity, neglecting the elasticities of other energy sources. In this regard, potential variables (degree of industrialization, urbanization and institutional quality) have been analyzed in addition to the traditional economic variable (income and price). Pakistan was ranked among the most urbanized countries of South Asia with a rise of 47% in urban population growth in 2010 (ADB). This rise in urbanization has increased the transportation usage by 300% (Pakistan Economic Survey, 2012), which leads to more energy consumption. In addition to urbanization, institutional quality has also been analyzed as a key determinant of energy specifically electricity consumption (Pierre and Rothstein, 2011; Rothstein and Teorell, 2008; Acemoglu and Robinson, 2006; Deacon et al., 2003 and Boix et al., 2003). Provision of energy goods (i.e. electricity and natural gas) to the population requires huge government funding. It is completely politically driven and depends on the political and administrative system of a country (Azam, Liu and Ahmad, 2020). The government of Pakistan has conducted several rural electrification and gas provision programs since 2007, under the power sector development programs to raise the socioeconomic standards of people living in the rural areas (Pakistan Economic Survey, 2020). In the wake of 2015, Pakistan invested heavily in its energy infrastructure, through China Pakistan Economic Corridor (CPEC) projects (Malik et al., 2020). Despite significant investments in energy infrastructure (especially in power generation), Pakistan continues to be energy insecure. The rural area in particular, suffered from 8-12 hours of power outages, in the peak of summer seasons. While, the gas pressure or supply is low during the winter season (Lin and Raza, 2020). Hence, including institutional quality as a determinant of energy consumption will provide useful insights to analyze the extent to which Pakistan's energy consumption can be attributed to its democratic status and institutional quality. It will also assess whether the extensions of national grid system ensures the availability of electricity to the targeted population. Previous studies on Pakistan's energy consumption have ignored this variable. In order to overcome this gap, the institutional quality index has been analyzed as a determinant of energy consumption which has been constructed by using data from International Country Risk Guide (ICRG).

Furthermore, this essay also estimates the degree of substitutability of energy with other factors of production (capital and labor) and the degree of substitutability among fuels (electricity, natural gas and petroleum products). Inter fuel and inter factor substitutability holds great importance to evaluate sustainability options through its impact on energy demand, fuel prices and also the growth of output. Considering the widening supply demand gap and high degree of vulnerability to oil price shocks it is much needed to investigate the potential of inter fuel substitution among various energy sources. The energy sector is poorly managed with extensive power and gas theft. In the year 2017–18, power generation consumed almost 37% of the primary energy supplies. Over 55% of the primary energy used for electricity was lost during generation and another 7% in transmission and distribution (MOE, 2018). Generation losses tend to be high in thermal power plants (oil, gas and coal), ranging from 40% to 60% (Lin and Raza, 2020). Analyzing the substitution possibilities among the energy sources will help in formatting technological approaches in order to combat the supply deficiencies and conserve energy. For this purpose this study uses a trans-log production function for the estimation of substitution elasticities between capital, labor, electricity, petroleum and gas after estimating their output elasticities covering the period 1980-2019. The output elasticities will provide useful information for economic growth by determining the critical inputs.

The second essay comprises of a micro analysis of the energy consumption at household level using data from Pakistan Social and Living Standards Measurement Survey (PSLM) making a comparison over three years i.e. 2005-06, 2010-11 and 2015-16. The domestic sector contributes a significant portion in total energy consumption. Successive governments have been reluctant in passing the burden of costly power production to users by providing power subsidies that has resulted in high circular debt[1] (Afia, 2020). In order to maintain tariffs below the tariff rate notified by NEPRA (National Electric Power Regulatory Authority), the government has to allocate a significant portion of the in budget (Rs.3.1 trillion) for subsidies which is not only unaffordable but also diverts resources from other priorities (Budget in brief 2020-21). The electricity consumption patterns shows that it is highly skewed towards the residential sector which accounts for 49% of the total power consumption during 2018 while that of the industrial sector was 26%. Such a consumption pattern is not only increases the inefficient use of electricity but also has severe consequences due to high amount of subsidies given to the residential sector (Malik et al., 2020). Moreover, the contribution of the residential sector to transmission and distribution loses is greater than other sectors (State bank, 2014). The literature on household energy demand in case of Pakistan is outdated. This essay seeks to examine in detail the intertemporal patterns of household expenditure on three main energy sources i.e. electricity, natural gas and petrol and diesel. Previous studies on energy demand by the household sector have not analyzed the demand for petrol and diesel along with the other fuels consumed by the households (HHs). In order to analyze the impact of changing energy prices in response to the international oil price shocks, it is necessary to consider

[1] Detail in chapter 2

the consumption of petrol and diesel by HHs as the petroleum products are directly influenced by such changes. There have been significant variations in the international energy prices over these years. This essay aims to analyze how the demand behavior has changed in response to these changes. The residential sector contributes a significant portion in the total energy consumption especially in case of power consumption (49%). Therefore analyzing the household energy consumption by using the expenditure data provides useful insights on how the demand for energy has evolved over time. The energy expenditures on different energy sources such as electricity, gas and petrol will be individually analyzed along with the estimation of income and price elasticities separately for urban and rural households. These elasticities provide vital information for policy makers to estimate the influence of price changes and design suitable policy like subsidy or tax reforms.

The third essay focuses on the issue of power subsidies and analyzes the effect of removing power subsidy on 4 sectors i.e. residential, commercial, industry and agriculture. It also analyzes the extent of cross subsidization among these sectors and within residential sector. Over the years, substantive cross-subsidization among sectors has led to skewed consumption towards the less productive residential consumers (Afia, 2020). Resultantly, the domestic consumption of electricity has increased substantially. Due to expensive electricity, the industrial sector has to depend on other sources of energy which affects their productivity adversely (Burgess et al. 2020). This essay also analyzes the impact of electricity price reform (2013) on consumer welfare.

Pakistan has been subsidizing residential electricity prices to ensure access to affordable energy to households. The electricity prices are not only highly subsidized but are also non transparent for some of the sectors which are compensated by charging higher prices from other sectors (Afia, 2020). During the past decade the electricity subsidy has been more than 2 percent of GDP which has been financed by national debt. The government did not allow the power companies to raise prices assuring them a compensation in the form of subsidies. However, as the subsidies were not paid by the government the power companies had to borrow to make their payments to the fuel suppliers with some unable to borrow any further (Elizabeth, 2012). As a result the fuel supplies have been curtailed which led to further reduction of generating capacity of the power companies. In the past five years the country has paid more than one trillion rupees in order to finance subsidies and loses of the power companies owned by the state. In the recent years (2018-19) the government has made some reforms to the electricity subsidies reducing their budgetary cost to 0.5 percent of GDP. This has been achieved partly through cuts in subsidies along with declining cost of energy worldwide which indicates that any rise in international energy prices would be either absorbed in debt or will be included in the consumer end prices passing the burden to the consumers. Due to these reforms, the amount of subsidies have declined significantly raising the prices of electricity. Any increase in the price of electricity impacts the welfare of households adversely especially the low income households. Therefore, analyzing the welfare loses due to higher tariffs (after the policy reform) especially for the poor households is necessary to understand the effectiveness of such policy reforms for providing protection to the poor. In order to address the issue of welfare loses due to higher tariffs (after the policy reform) especially for the poor households, the third essay estimates the benefit incidence of electricity subsidies on five different income groups of households using PSLM micro data for the year 2011-12 and 2015-16.

This dissertation is organized as follows; Chapter 2 analyzes the energy consumption at sectoral level and estimates the possibilities of substitution among factor inputs. Chapter 3 analyzes the energy consumption patterns and demand elasticities at the household level and Chapter 4 estimates the impact of electricity policy reform and subsidy removal on consumer welfare. In the end, a consolidated conclusion is given of the complete dissertation.

Chapter 2

Energy Consumption and Possibilities of Inter-factor Substitution in Pakistan

2.1 Introduction

Pakistan has experienced a rapid growth in primary energy demand over the last few decades. The primary energy demand has increased by 150% in the last twenty years. However, the supply has not increased in accordance to the rise in demand due to several constraints such as circular debt, increased reliance on oil/gas, decline in gas reserves, inadequate exploitation of coal reserves and underutilization of power generating units (Ali, 2020). The energy crisis has become an inevitable challenge due to inefficient resource management, lack of investment in the infrastructure and absence of a well-planned policy (Alahdad, 2012). The existing energy mix of Pakistan is highly reliant on gas, oil and expensive fuels instead of coal and hydel. The dependence on imported oil which is about 85% of the total supply is not only making the energy mix unfavorable but is also adding to the fiscal burden.

Due to the escalating demand of electricity, there has been increase in the thermal generation of electricity in addition to hydro projects (Siddiqui, 2004; Ahmad and Khan, 2008; Kotani and Qasim, 2014). The thermal generation of power makes use of furnace oil which is not only expensive but also has to be imported. In the course of the previous 7 years the price of furnace oil has witnessed an increase of 60 % exerting pressure on Pakistan's external account. Successive governments have been reluctant in passing the burden of costly power production to users by providing power subsidies that has resulted in high circular debt (Malik, 2012). In order to maintain tariffs below the tariff rate notified by NEPRA (National Electric Power Regulatory Authority), the government has to allocate a significant portion of the budget (Rs. 3.1 trillion) for subsidies which is not only unaffordable but also diverts resources from other priorities (Budget, Briefs, 2020)

The government of Pakistan has invested around $34 billion in the power sector with an aim to enhance the power production capacity. However, the energy crisis in Pakistan is not just a predicament of supply shortages rather it is manifold; including supply side as well as demand side issues. In view of the current challenges, two important issues have been addressed in this chapter. Firstly, it seeks to analyze why the energy pricing policy reforms have not been successful in increasing the efficient use of energy? In order to ensure efficient use of energy the pricing policy has also undergone a number of changes. OGRA which conduct publics hearings and set prices for natural gas and petroleum products have capped the petroleum products prices in different periods (Afia, 2008). On the other hand several reforms have been made in the power sector for improving bill collection and reducing the shortfall in the generation capacity.

Despite the pricing policy reforms, the energy demand and supply gap has further widened due to the inefficient use and wastage of energy resources (Annual report of the State Bank, 2018). In order to address this question, this chapter extends the existing literature on energy consumption by analyzing the demand functions of energy sources (Electricity, natural gas and petroleum products) for different economic groups (i.e., households, industry, commercial and agricultural sectors). In this context, this study incorporates other potential variables (degree of industrialization, urbanization and institutional quality) in addition to the traditional economic variable (income and price). Pakistan was ranked among the most urbanized countries of South Asia with a rise of 47% in urban population growth in 2010 (ADB). This rise in urbanization has increased the transportation usage by 300% (Pakistan Economic Survey, 2012), which leads to more energy consumption. In addition to urbanization, institutional quality has also been analyzed as a key determinant of energy specifically electricity consumption. Previous studies suggest that institutional quality and democracy are positively related to energy consumption as they increase the provision of public goods (Pierre and Rothstein, 2011; Rothstein and Teorell, 2008; Acemoglu and Robinson, 2006; Deacon et al., 2003 and Boix et al., 2003). Provision of public goods such as access to electricity and natural gas requires large scale transmission and distribution infrastructure and long term investment which is highly expensive (Abbott, 2001). In most countries electrification programs specifically rural electrification have been conducted through government funding and special national programs (Zomers, 2003). Therefore, provision of energy goods (i.e. electricity and natural gas) to the population is completely politically driven and depends on the political and administrative system of a country. The government of Pakistan has also conducted several rural electrification and gas provision programs since 2007, under the power sector development programs to raise the socioeconomic standards of people living in the rural areas. The village electrification and gas provision programs have always been an integral part of the government agenda in Pakistan (Pakistan Economic Survey, 2020). Hence, including institutional quality as a determinant of energy consumption will provide useful insights to analyze the extent to which Pakistan's energy consumption can be attributed to its democratic status and institutional quality. It will also assess whether the extensions of national grid system ensures the availability of electricity to the targeted population. However, previous studies on Pakistan's energy consumption have ignored this variable. In order to overcome this gap, the institutional quality index has been analyzed as a determinant of energy consumption which has been constructed by using data from International Country Risk Guide (ICRG). The index has been constructed by taking an average of Pakistan's government stability, investment profile, law and order, corruption, democratic accountability and Bureaucratic Quality.

In case of Pakistan, there are only a few studies that analyze the demand elasticities for energy products (Iqbal, 1983; Siddiqui and Haq, 1999; Javid & Qayyum, 2014). Mostly studies have analyzed the demand function only for electricity. Other energy sources like gas and petroleum products also account for a significant portion of the total energy demand. Secondly, this chapter analyzes the technical possibilities to overcome the supply deficiencies and improve the energy security. Considering how the rise in international oil prices has made the energy production so costly specifically the thermal generation of power using expensive imported furnace oil in the recent years, this chapter tries to suggest possible technological approaches to meet the energy requirements by examining the extent of inter-fuel and inter-factor substitution. The literature on substitution possibilities among factor inputs is very limited in case of Pakistan. Most of the previous studies aimed at the removal of allocative inefficiencies which create over and underutilization of factor inputs relative to their factor endowments. However, these studies have not addressed the possibility of inter fuel substitution. In view of the widening supply demand gap and high degree of vulnerability to oil price shocks it is much needed to investigate the potential of inter fuel substitution among various energy sources. Analyzing the substitution possibilities among the energy sources will help in formatting technological approaches in order to combat the supply shortages. For this purpose this study uses a trans-log production function for the estimation of substitution elasticities between capital, labor, electricity, petroleum and gas after estimating their output elasticities covering the period 1980-2019. The output elasticities will provide useful information for economic growth by determining the critical inputs. Estimating the substitution elasticities will help to substitute the less costly inputs in order to conserve energy.

2.1.1 Objectives of the Study

The broad objectives of this chapter are as follows:

1. To analyze the responsiveness of different economic sectors towards the changes in energy prices using energy demand estimates for three main sources of energy i.e. electricity, natural gas and petroleum products.
2. To examine the important determinants of energy consumption for different economic groups (residential, commercial, industry etc.)
3. To estimate the possibility of substitution within energy products (electricity, natural gas and petroleum products) and between energy and non-energy factors (capital and labor).

2.1.3 Contribution of the Study

This study contributes in the existing literature in the following ways:

- This study incorporates other potential factors (degree of industrialization, urbanization and institutional quality) in addition to the traditional economic variables (income and price) by using updated data in order to estimate a correctly specified demand function along with price elasticities. Pakistan was ranked among the most urbanized countries of South Asia with a rise of 47% in urban population growth in 2010 (ADB). This rise in urbanization has increased the transportation usage by 300% (Pakistan Economic Survey, 2012), which leads to more energy consumption. In addition to urbanization, institutional quality has also been analyzed as a key determinant of energy specifically electricity consumption. Previous studies suggest that institutional quality and democracy are positively related to energy consumption as they increase the provision of public goods (Pierre and Rothstein, 2011; Rothstein and Teorell, 2008; Acemoglu and Robinson, 2006; Deacon et al., 2003 and Boix et al., 2003). Including institutional quality as a determinant of energy consumption will provide useful insights to analyze the extent to which Pakistan's energy consumption can be attributed to its democratic status and institutional quality. It will also assess whether the extensions of national grid system ensures the availability of electricity to the targeted population. Previous studies on Pakistan's energy consumption have ignored this variable. In order to overcome this gap, the institutional quality index has been analyzed as a determinant of energy consumption which has been constructed by using data from International Country Risk Guide (ICRG).

- Considering how the rise in international oil prices has made the energy production so costly specifically the thermal generation of power using expensive imported furnace oil in the recent years, this study tries to suggest possible technological approaches to meet the energy requirements by examining the extent of inter-fuel and inter-factor substitution. It is not sustainable for Pakistan to feed its energy requirements through imported thermal fuels, more than half of which tend to be lost during generation and transmission (Lin and Raza, 2020). The research on inter fuel substitution is very limited in case of Pakistan (Mahmood, 1989; Mahmud and Chishti, 1990; Mahmud, 2000). All these studies focus on the large scale manufacturing sector of Pakistan and employment generation rather than energy conservation covering the period before 2000, whereas this study uses recent data (1980-2019).

2.1.4 Organization of the Study

The remaining chapter is organized as follows. Section 2.2 gives an overview of the sector wise energy consumption of Pakistan. Section 2.3.reviews the existing literature on energy and substitution possibilities among energy sources. Section 2.4 gives the theoretical framework, Section 2.5 gives the data and econometric Methodology, and Section 2.6 discusses the results while Section 2.7 concludes the chapter.

2.2 Energy Consumption in Pakistan (Sector Wise)

Over the last decades, the Pakistan has been facing severe energy crisis due to insufficient energy production to fulfill the escalating demand. The energy supply has increased by more than 40 times during the past 25 years (NBP, 2008), yet the demand outweighs the supply. The phenomenal growth of energy consumption is caused by the increased economic activities and growth of industrial, agriculture and service sectors along with the increasing population. Early in 1950's, Pakistan energy situation was shaped by successive discoveries of natural gas reserves. This led to the growth of large public sector gas distribution utilities. Most of the major power plants and domestic fertilizer industries were based on natural gas. The share of natural gas was approximately 50% during 2005. In the absences of any additions to the gas fields, gas production has plateaued. Major share of the energy demand burden is now on imported oil. Recently, the declining share of domestic gas supplies are being offset by imported LNG and coal (Malik et al., 2020). During 2017-18, total energy supplies consisted of 35% indigenous gas and 31% of oil (MOE, 2018).The demand supply gap has further widened by the inefficient use and wastage of energy resources (Figure 2.1).

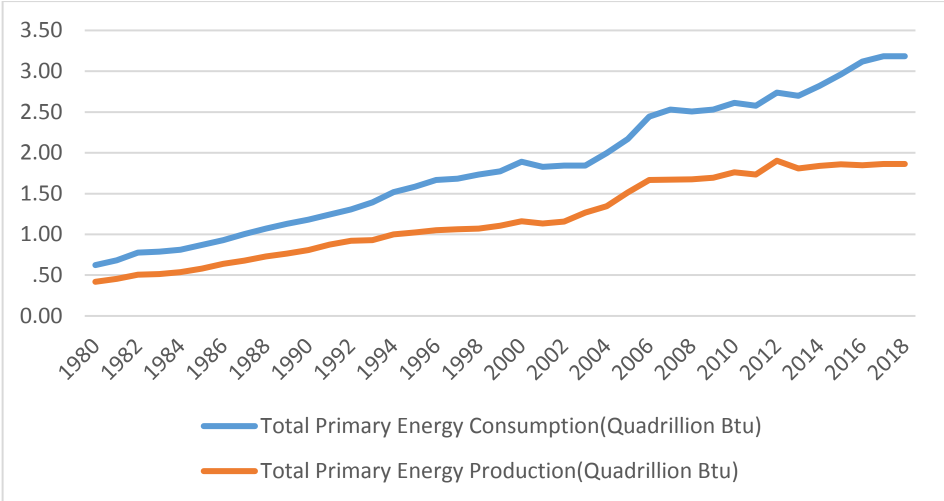

Figure 2.1: Supply and Demand gap of primary energy of Pakistan

Source: IEA, 2019, Note: quad=10^{15} BTU (British Thermal Unit)

In 2017, primary energy (coal, natural gas, nuclear, hydro, bio fuels and waste, oil, wind and solar energy) consumption for Pakistan was 3.18 quadrillion btu. Primary energy consumption of Pakistan increased from 1.73 quadrillion btu in 1998 to 3.18 quadrillion btu in 2018 growing at an average annual rate of 4.19% (International Energy Agency, 2019). While, the production of primary energy was 1.86 quadrillion btu. Primary energy production of Pakistan increased from 1.07 quadrillion btu in 1998 to 1.86 quadrillion btu in 2018 growing at an average annual rate of 3.69%.

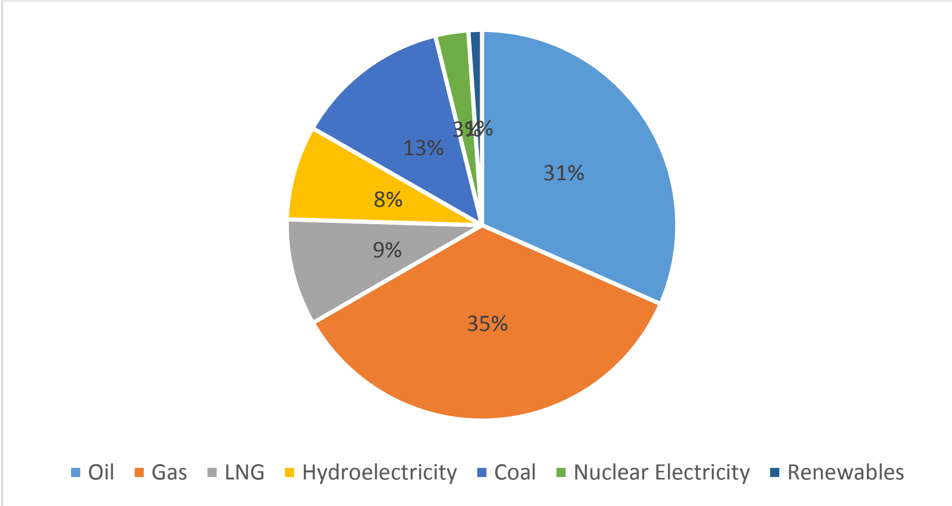

Figure 2.2: Energy Mix of Pakistan 2018-19

Source: Pakistan Economic Survey 2018-19

The energy generation of Pakistan relies greatly upon oil and gas that attributes to 77% of total energy produced. In terms of energy mix, the dependence on oil has declined to 31.2% in the FY2018, which was recorded as 43.5% in the period 1998-2001 (Figure 2.2). The share of hydroelectricity has reduced to 7.7% in 2017-18 which was 13.1% in 1998. Although the declining share of oil has reduced the fiscal burden, as a result of shortsightedness of policy makers, the successive administrations have failed to increase the hydro power generation. The dependence upon natural gas which was the highest in FY2006 (50.4%) has now reduced to 34.6% in the FY2018. This decline in the energy mix is due to the exhausting reserves of natural gas in addition to the restricted consumption by the transport sector (shown in Figure 2.3) and the usage of Liquid Natural Gas (LNG) since 2015 which has increased to 8.7% in 2018 (Pakistan Economic Survey 2018-19). The share of coal has increased to 12.7 percent and that of nuclear electricity gradually improved to 2.7% which was 0.2% in 1997.

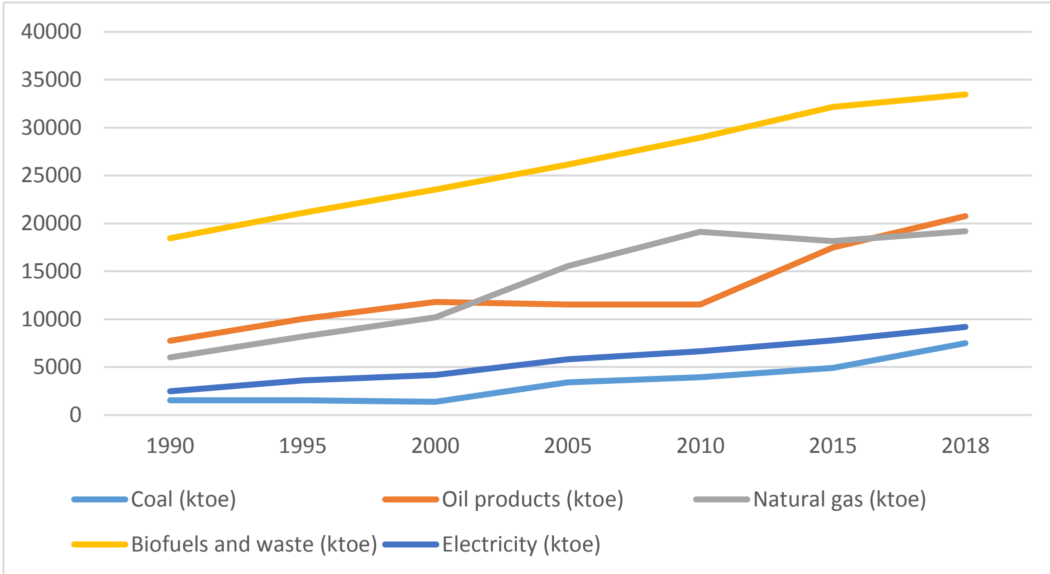

Figure 2.3: Energy consumption by Source

Source: IEA, 2019

The energy needs are expected to increase three folds by 2050 while the supplies are not very inspiring. Moreover, the inter-sectoral patterns of consumption have changed significantly over time (Figure 2.4). The industrial sector has the largest share in total energy consumption followed by the transport and household sector. After experiencing a high growth, the industrial consumption started to decline in the wake of global oil crises during 2008, with a rise in the transport share correspondingly. The total energy consumption showed a decline during 2008-09 which later on increased at a fast pace after 2014. On the other hand, the household sector has been witnessing a constant rise after 2008 with a peak of 25 percent in 2012-13.

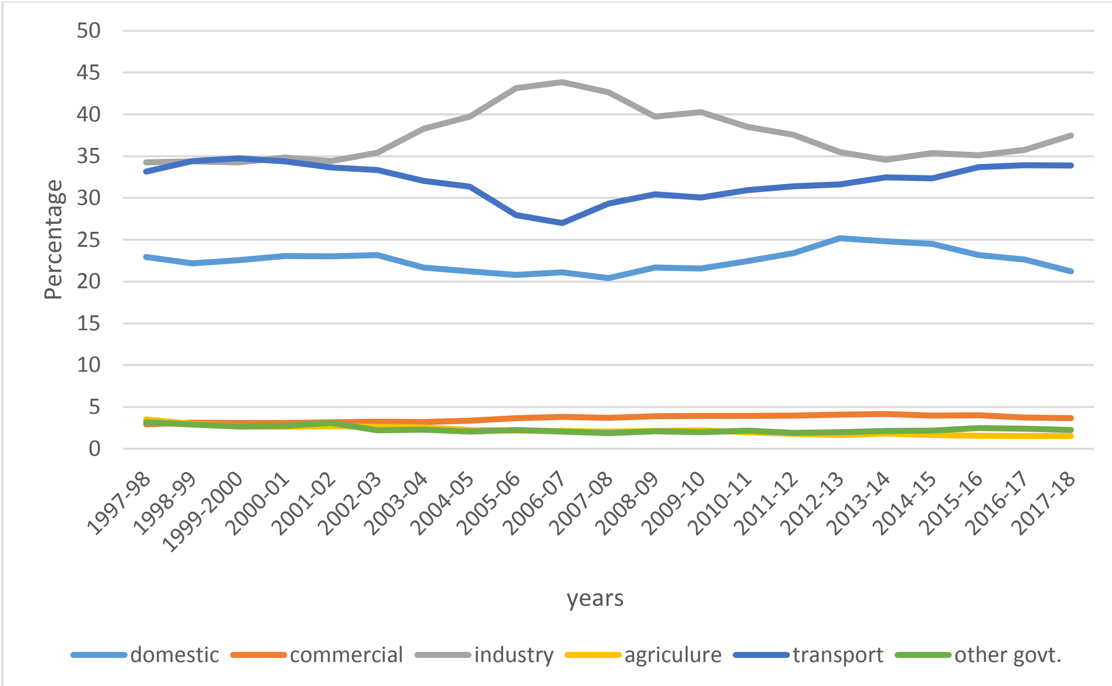

Figure 2.4: Energy consumption by Sectors (% share)

Source: Pakistan Energy Yearbook (various issues)

The fall in share of industry and the corresponding rise in share of transport can be attributed to several factors. Firstly, the slowing down of industrial growth due to declining growth momentum of the economy reduced demand for energy. Secondly, the rising oil prices post 2008 led to substitution of petrol/ diesel for CNG in the transportation sector, increasing energy demand in this sector. The energy needs are expected to increase three folds by 2050 while the supply situation is not very inspiring (Hilali, 2019). The primary energy sources and their issues are discussed in details in the forthcoming subsections.

2.2.1 Oil (Petroleum Products)

The energy requirements in Pakistan are mostly fulfilled by gas and oil. However the indigenous oil resources fall short of the growing demand which has led to the importation of oil and petroleum products in huge amounts from the Gulf countries. As a result Pakistan has faced massive oil supply disruptions on several occasions such as Iranian boycott from

1951 to 1953, war between Arab Israel (1973), revolution of Iran (1979), war between Iran and Iraq (1980) and the global financial crisis in 2008. The international oil prices have been increasing since 1990's. The oil price which was $10/barrel in 1995 escalated to $110/barrel in May 2014 leading to a rise in oil price domestically from Rs.9 per liter (1995) to Rs.107 per liter in May 2014 (Figure 2.5). The international prices of oil exhibited significant volatility in 2014 and declined to the same level as in 2010 due to persistent increase in US crude stocks and higher supplies from OPEC producers (Middle East).

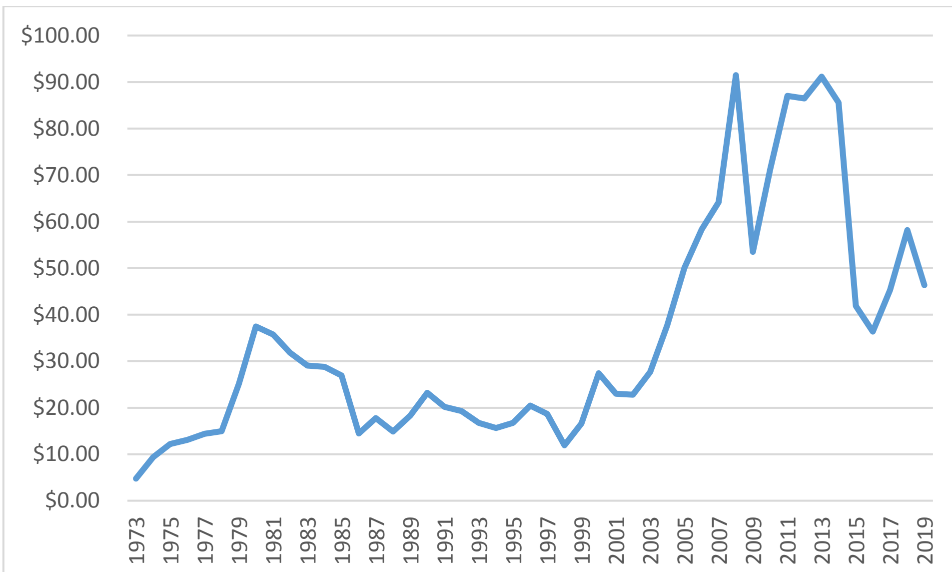

Figure 2.5: Crude Oil Prices (US $/Barrel)

Source: IEA, 2019

The federal government responded to the falling international prices of oil by lowering the petrol prices to Rs.69.09 per liter (2016-17). Due to the soaring international oil prices (after declining for three years), the prices of LPG, petroleum and diesel increased with petrol prices reaching up to Rs.95.39 per liter in April 2019 (Figure 2.6).

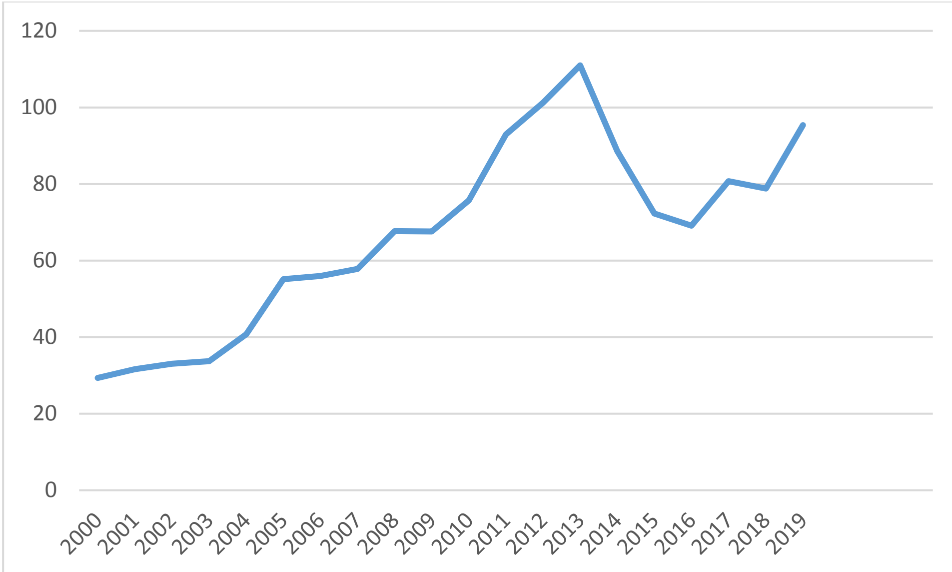

Figure 2.6: Petrol Prices in Pakistan

Source: Pakistan Economic Survey, Ministry of Petroleum & Natural Resources

In early 1990s, the main users of oil/petroleum products were the power and transport sector which had a share of 50% and 25% respectively in the total consumption. As a result of a continuous rise in the prices of crude oil there was a significant reduction in the demand for oil/petroleum products in the period of 2000-2006. The prices rose by almost 118 percent from US $ 22.99 per barrel (2001) to US $ 50.04 per barrel. Realizing the accelerating prices of oil, the government of Pakistan, initiated a pro-market reform in the year 2000, in order to limit its role for policy issues whereas, the regulation of prices were to be conducted by an independent regulatory authority. Until 1999, the prices of petroleum products were controlled by the government. The government was the sole decision maker in this sector and had a tight control over the petroleum and crude oil prices. The guaranteed return formula (i.e. return was kept under 10% to 40% of the refineries equity and any loss in the refineries profitability was met by the government) of the refineries was also changed to an IPP (import parity price) formula under which the ex-refinery prices are determined by applying an import tariff to the FOB (Free on Board i.e.

buyer has to bear the shipping cost completely) price of the petroleum product (Ansari and Unar, 2014). In 2001, the government approved Oil Companies Advisory Committee (OCAC) for reviewing and fixing prices of petroleum products in accordance of the pricing formula on fortnightly basis. The OCAC fixed the prices of petroleum products in accordance with the approved pricing formula (Appendix A1) during the period of July 1, 2001 and April 1, 2006. From April 16, 2006, the Oil and Gas Regulatory Authority (OGRA) was given the responsibility to fix prices. In order stabilize the final price the government has often adjusted the Petroleum Development Levy on ad-hoc basis. OGRA is advised by the government on fortnightly basis about PDL. During a short period of one and a half year (July 2006 -December 2007) OGRA and OCAC have changed the prices 156 times. However, the government has regulated the prices of petroleum products many times in order to provide protection to the consumers from the influence of escalating international prices of crude oil.

Since Feb 2009, the consumer prices are notified on monthly basis by OGRA. The domestic prices were linked with oil prices in the global market. The state also deregulated prices of High Octane Blending Component (HOBC), Jet Propellant 1 (JP1), Jet Propellant 4(JP4) and Jet Propellant 8 (JP8), Light Diesel Oil (LDO) and Motor Spirit (MS) in 2011. Furthermore, the POL prices were linked with the import prices of Pakistan State Oil (PSO) under the deregulation framework. Oil Marketing companies (OMC's) and Refineries were allowed to fix the ex-refinery and ex-depot price on monthly basis. In case the import prices are not available, the IPP formula was used. General Sales Tax (GST) on depot prices has also been included in the sales price. At present OGRA only computes prices for kerosene oil and notifies the Inland Freight Equalization Margin (IFEM) for the petroleum products.

Despite the deregulation of the prices of petroleum product (jet fuels, light diesel oil, motor spirit and HOBC), the government still has substantial control on the retail prices through modifications in the sales tax. The government changes the sales tax rate according to its policy and revenue targets. The sales tax on LDO and Kerosene oil was about 30% in 2015 which was reduce to 0% in the end of 2016 in order to provide protection to the poor and low income groups. During 2016, despite of the decline in the international oil prices the government raised the sales tax on petroleum products. In June, 2017 the sales tax on motor spirit was fixes as 20%, while for HOBC it was fixed as 15% and 34% on HSD. In addition to the sales tax, petroleum levy is another means through which the government influences the prices of petroleum products indirectly. The purpose of designing the petroleum levy was to provide financial help in order to develop and upgrade the petroleum sector, however it has been extensively used to create revenues in order to finance budget deficit. In 2017, the revenues generated by petroleum levy amounted to Rs.167 billion.

During fluctuations in the international oil prices, Pakistan has focused on reducing the reliance on importation of oil. The production of crude oil in 2016 was 24.02 million barrels while 4.98 MMt (million metric tons) was imported (Pakistan Economic Survey 2015-2016). On the other hand the demand for petroleum products is also greater than the oil refining capacity which is why half of the imports constitute of refined products (Figure 2.8). The import of petroleum products contributed to the import bill by 17% in 2017. As international oil prices remained high in 2018, the cost of imported energy escalated by 25% ($13.3 billion) raising the contribution of imported energy to 37% in the import bill (State Bank Annual Report 2018-19).

In case of petroleum products consumption, the transport sector has the largest share with an increasing trend especially after the fall in world oil prices. During 2018-19 transport sector had the largest share in petroleum products consumption (80%), followed by industry (9%), while commercial sector contributed a 4% share, domestic sector had 3% and agriculture sector had the smallest share of 0.1% (Figure 2.7).

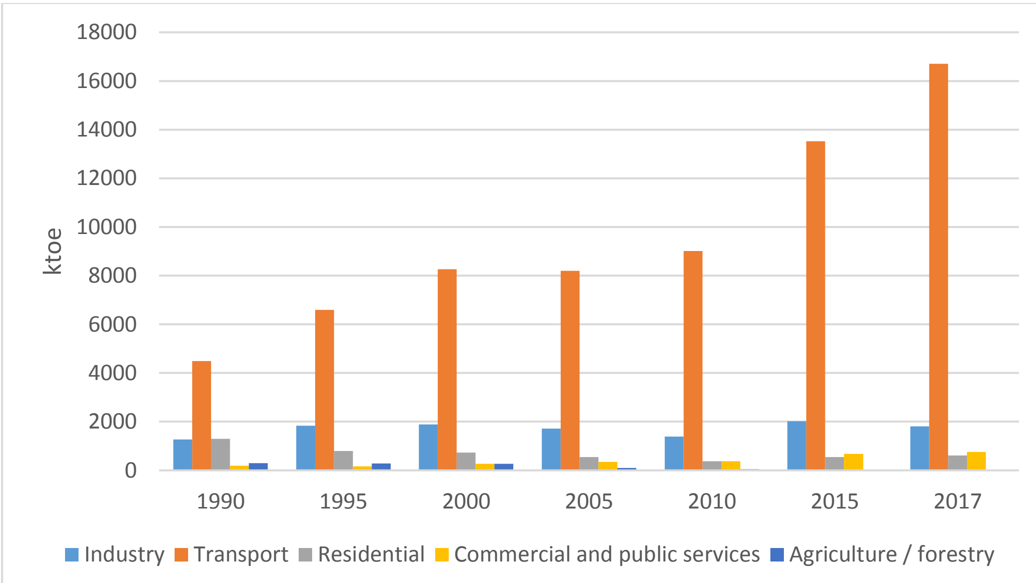

Figure 2.7: Petroleum Products Consumption by Sectors

Source: Pakistan Energy Yearbook (various issues)

In the coming years the demand of petroleum products is expected to grow at a faster pace as compared to the production making is impossible for Pakistan to gain self-sufficiency, given the volume of oil resources. During 2018-19, the consumption of petroleum products was 20.03 million tones, out of which 2.8 million tons were domestically produced. In order to overcome the high cost of imported oil and petroleum products, there is a need to improve the necessary infrastructure of the oil refineries which requires considerable amount of investment. Although the government has introduced several incentives to attract investment by the private sector in the Petroleum policy 1997, still it has failed to achieve satisfactory results.

2.2.2 Compressed Natural Gas

Natural gas contributes 48% of the energy mix of Pakistan. The gas production is based on the domestic supply by public and private companies. It consists of 2 semi-state owned gas T&D (transmission and distribution) companies, Sui Northern Gas Pipelines Limited (SNGPL) and Sui Southern Gas Company Limited (SSGCL). There are 31,058 services gas pipelines which provide 4 billion cubic feet of natural gas daily to meet the requirements of 7.9 million consumers (Raza et al., 2020). The average natural gas consumption during 2015-16 was 3387 cubic feet per day. Figure 2.8 shows the trend of primary energy supplies that clearly indicates the increase of gas share outstripping the oil share in starting years of 2000 but gradually falls in the wake depleting reserves and stagnant production.

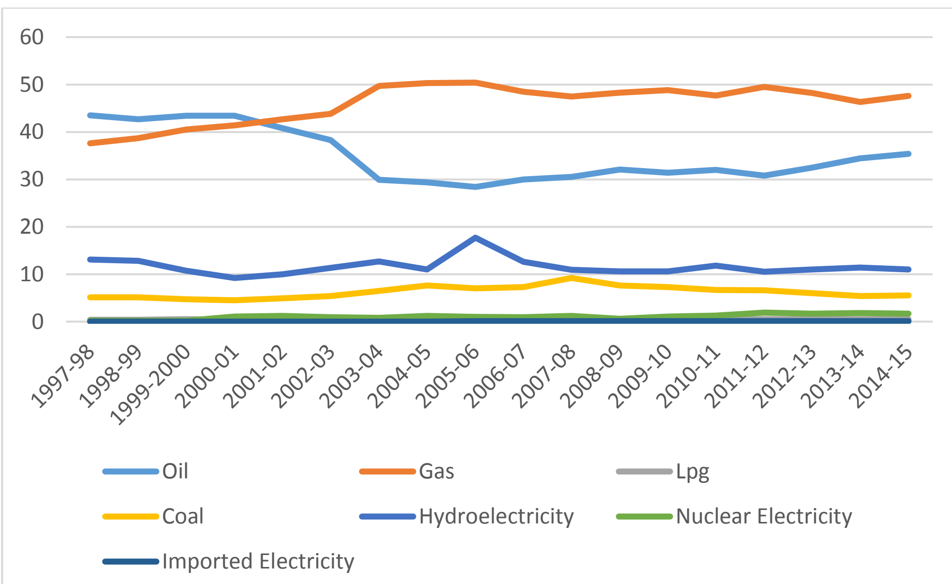

Figure 2.8: Primary Energy Supplies by source

Source: Pakistan Economic Survey 2018-19

Most of the gas supply comes from the fields of Sindh and Sui district Baluchistan. The province wise production and consumption is given in the Table 2.1:

Table 2.1: Production and consumption of natural gas

Province	Production	Consumption
Sindh	69%	41%
Balochistan	17%	7%
KPK	9%	7 %
Punjab	5%	45%

Source: Pakistan economic Survey 2017-18

The price of natural gas is revised biannually following the prices of High Sulphur Fuel Oil (HSFO) and crude oil. The prices of crude oil effects the price of domestic well head gas which is then shifted to the user end prices. OGRA suggests the gas prices for utilities after computing the revenue requirement to the state. The revenue requirement by the gas utilities includes cost for depreciation, transmission and distribution, distribution loses (unaccounted of gas, UFG) and return for gas utilities which is 17.5% in case of SNGPL and 17% for SSGPL. After the inclusion of taxes, the government notifies price of natural gas for economic sectors i.e. residential, industry, commercial, transport and power. However, after the deregulation of the business sector (2016) business owners are permitted to fix price of compressed natural gas (CNG). Currently the sales tax on CNG is fixed as 17% by the state. In addition to sales tax the CNG consumers also pay a development surcharge (Natural Gas Development Surcharge, NGDS). The development surcharge is imposed for developing infrastructure of natural gas and equalization of prices within the country (Raza et al., 2019).

CNG was initially used as an alternate of automotive by the government as it is cheaper than the liquid fuel and also controls for environmental degradation. As a result the demand for CNG had a massive increase. Pakistan does not import Gas and presently has about 3416 CNG stations to fulfill the demand of more than 3 million vehicles running on natural gas. However, a ban has been imposed on the establishment of new CNG stations in view of the depleting reserves.

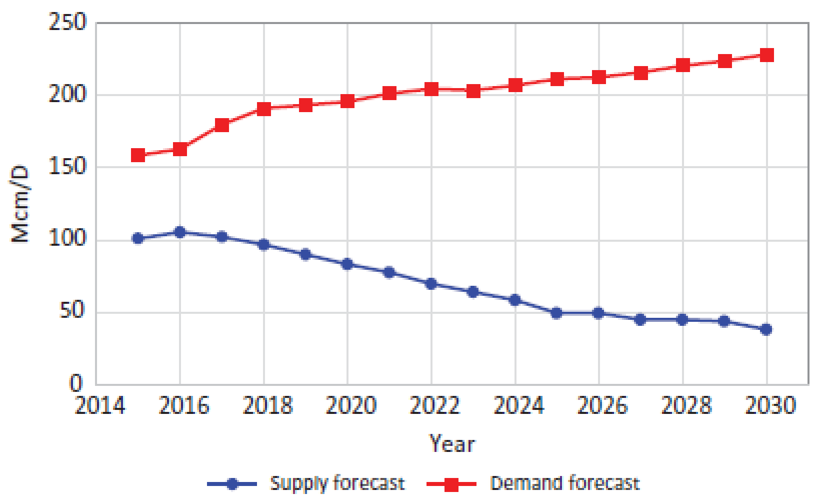

Figure 2.9: Demand and Supply of Natural gas (indigenous)

Source: OGRA, 2017

Despite being sufficient in gas supply Pakistan is also facing gas crisis in addition to electricity crisis. According to some estimates the country has entered the deficiency state after 2006 (Rauf et al., 2015). Before 2006, the local resources have fulfilled the demand of the domestic as well as the commercial and industrial consumers with an ample supply. The growth rate of as consumption increased rapidly during 2015-16 while the growth rate of production was 1.2%. The shortfalls of gas supply have leaded to gas load shedding and supply cuts especially in the winter seasons. The severity of this shortfall can be assessed by the decision of the government implementing load shedding of two days per week on

CNG stations and industries since November 2009 to March 2010 (Hhan et al., 2012). If this trend of gas consumption continues, the supply and demand gap will rise by 80 time till 2030 (Hathway and Kugelmn, 2012) as shown in Table 2.2.

Table. 2.2: Estimates of demand and supply of natural gas.

Years	**Demand (Mcf/day)**	**Supply (Mcf/day)**	**Net difference(Mcf/day)**
2004-2005	3173 Mcf/day	4033	860
2009-2010	4565 Mcf/day	4424	-141
2019-2020	9114 Mcf/day	3001	-6113
2029-2030	19035 Mcf/day	2299	-16736

Source: Hathway and Kugelmn (2009)

The activity of drilling wells has slowed down as private exploring and producing companies have inadequate involvement in exploration. The shortage has been substituted by alternative fuels like diesel and kerosene during the phase of 2005-10 increasing the share of oil from 29%to 31%. Until 2007, the power sector had the largest share in gas consumption. The use of gas for generating power is declining gradually in Pakistan. The industrial sector is also facing similar situation of gas supply cut. It has been estimated that 80% of the textile industry relies upon supply of gas from SSGCL and SNGPL (All-Pakistan Textile Millers Association (APTMA)). Due to massive gas shortage the annual opportunity loss was more than 5 billion dollars during the last four years (Economic Survey of Pakistan 2018). The government has also initiated rapid investment in the establishment, production and storage of the LPG stations. Approximately 2.38 billion rupees have been invested in the infrastructure of the sector of LPG during 2016 in order to enhance the private investment in the petroleum industry. LNG is also imported to meet the supply shortage of natural gas.

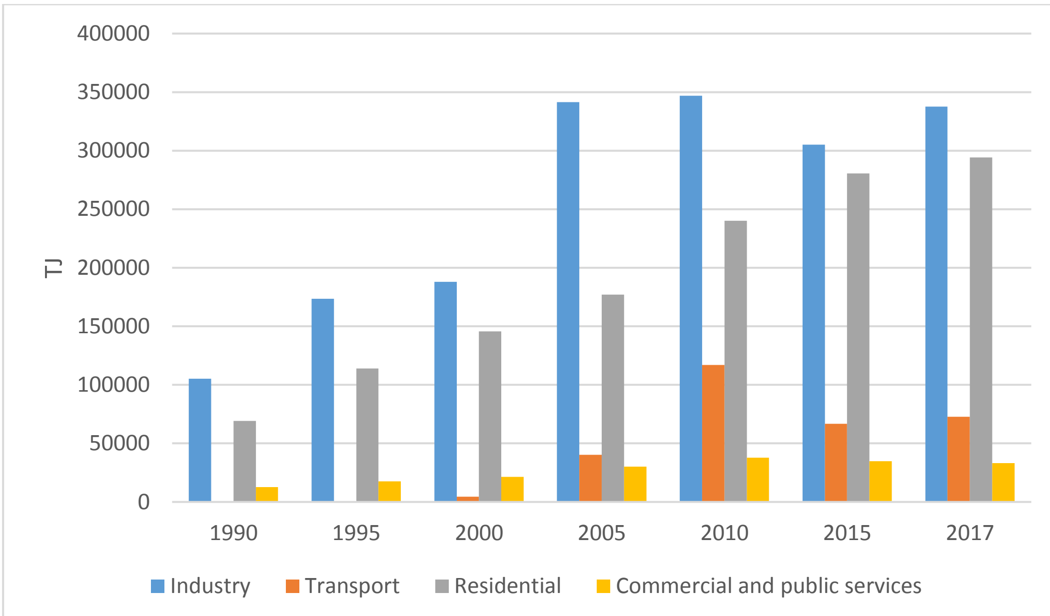

Figure 2.10: Natural Gas Consumption by Sectors

Source: Pakistan Energy Yearbook (various issues)

Analyzing the consumption pattern of natural gas reveals that the industrial sector constitutes the largest share in gas consumption. It is seen that from 2005 onwards the consumption share of natural gas of the transport sector has increased immensely. In order to reduce import bill on oil, the use of Compressed Natural Gas (CNG) as fuel for automobiles was encouraged through approval of marketing licenses of more than 3416 CNG stations by the state. In view of the depleting gas reserves a ban has been placed on establishment of new gas reserves. The total consumption of natural gas showed a decline during 2010-2015 with decreasing shares of the industrial and transport sector (Figure 2.10). This decline in consumption of natural gas is accompanied by the increase in oil fuel consumption in response to the declining prices of petrol. During 2018-19 the share of domestic sector was 33%, the share of industrial sector was 38 % and that of transport sector was recorded as 8% in the total consumption of natural gas.

2.2.3. Electricity

Power shortage has become a challenge for Pakistan. For almost a decade, the power crisis is prevailing in the country resulting in routine power outages, called "load shedding" in both urban and rural areas. Since 2007, the electricity supply shortfalls (5000-5500MW) have led to load shedding of long hours which in some areas has even averaged up to 17 hours per day (IMF, 2013).

Despite have an increase of 13,298 MW in the power generation capacity there is a persistent shortfall in the country during peak hours (Figure 2.11).

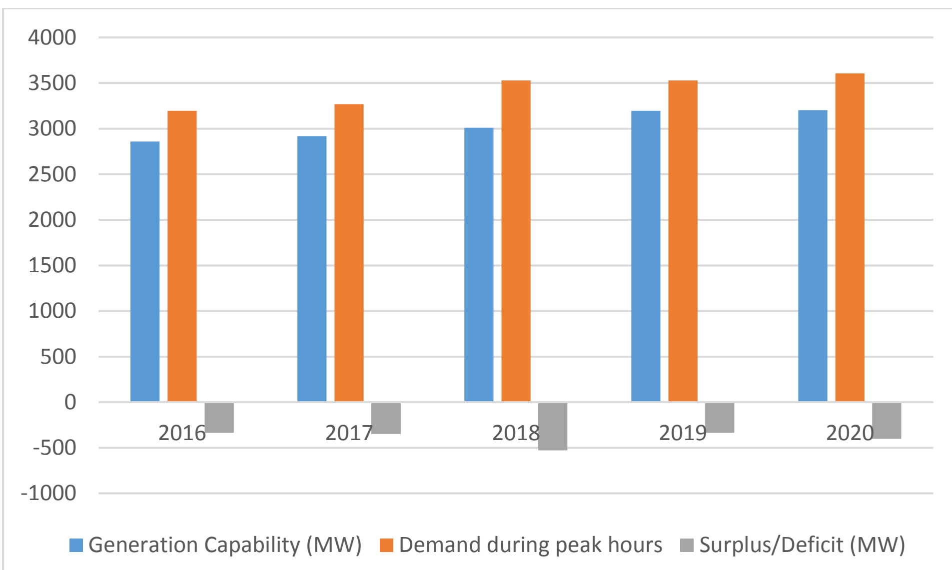

Figure 2.11: Peak demand, the capability of electricity generation and shortfall (MW).

Source: State of Industry Report, NEPRA (2020)

Projection for the demand and supply of electricity has been depicted in Figure 2.12. It is evident that there is continuous increase in the demand for electricity with an annual growth rate of 5-7%. In the hours of power cuts most households use gas fueled generators which adds to the inefficient use. According to Siddiqui, R., et al., (2008), the unserved energy due to power outages has caused an industrial output loss that is estimated to vary between 12% to 37% for four major industrial cities of Punjab—Gujrat, Faisalabad, Gujranwala, and Sialkot. These shortfalls have not only increased the production cost of firms due to alternative energy arrangements but also have caused delay in meeting supply commitments.

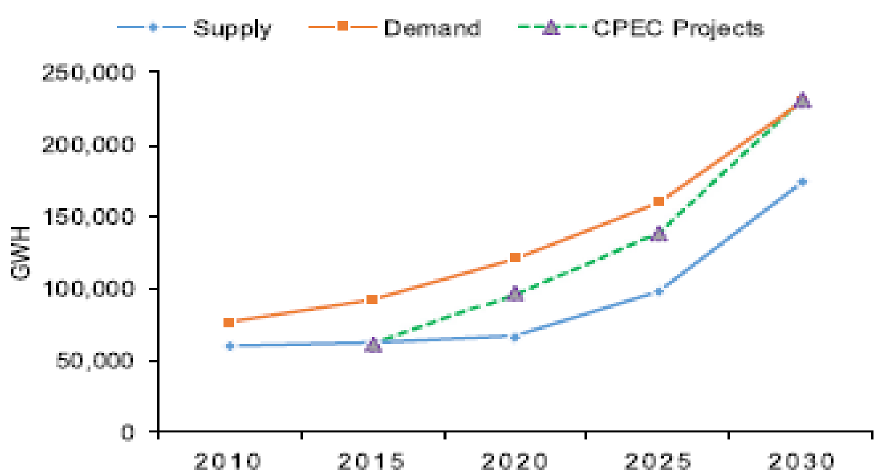

Figure 2.12: Projected supply and demand of electricity

Source: Iqbal et al., 2018

The projection of electricity supply is shown by the green curve incase if the energy projects under the CPEC program are completed on time (Irfan, Zhao and Panjwani, 2020). The government of Pakistan has invested around $34 billion in the power sector with an aim to enhance the power production capacity. However, the energy crisis in Pakistan is not just a predicament of supply shortages rather it is manifold; including supply side as well as demand side issues.

On the other hand, the source wise consumption patterns of sectors shows that the domestic sector contributes the largest share in electricity consumption over many years (Figure 2.16). During 2018-19, the consumption pattern followed the same historic pattern with a domestic share of 49%, industrial share of 26%, commercial share of 8% and agricultural share of 9%. There are severe consequences of such a large domestic share as according to the annual report of the State Bank,2014 the residential sector contribute more to the T&D losses than other sectors. Moreover, this sector is also highly subsidized.

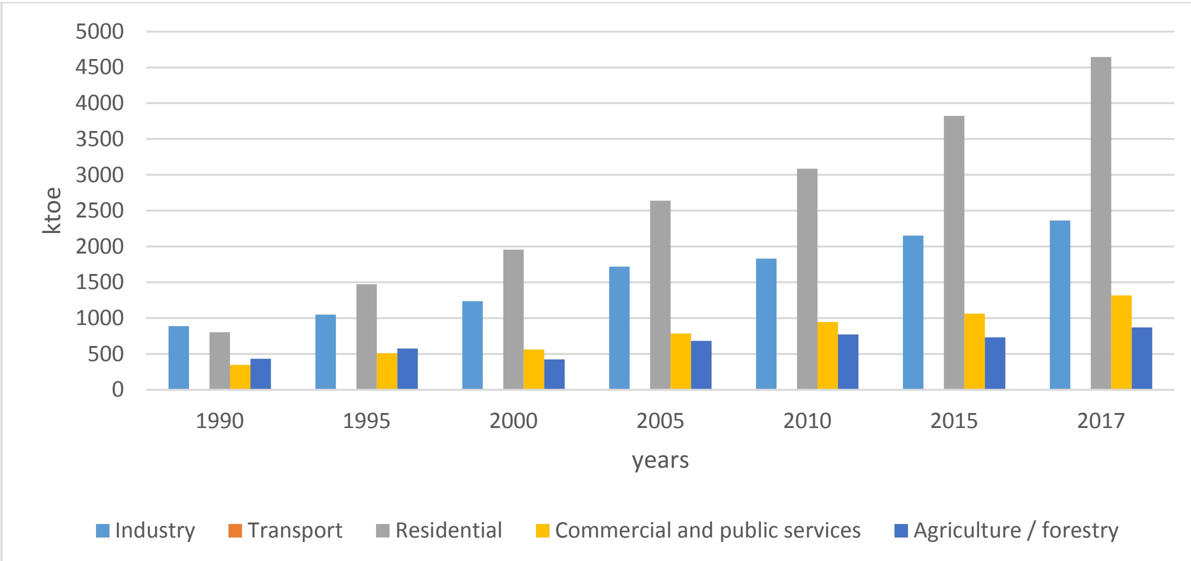

Figure 2.13: Electricity Consumption by Sectors

Source: Pakistan Energy Yearbook (various issues)

About fifty one million (27%) people of the population do not have access to power (IEA, 2017). Those that are connected have to experience load shedding of some hours on daily basis. In absence of reliable distribution network the rural households use LPG as a source of fuel which is more expensive as compared to the subsidized natural gas used by urban households.

2.3 Literature Review

The section of literature review contains two subsections. The first section presents the literature review on energy demand and its determinants. The literature review for the inter fuel and inter factor substitution is presented in the second subsection.

2.3.1 Literature Review on Energy Demand

Energy demand analysis has gained immense attention especially after the shocks in oil price (1973), in the phase of 1979 to 1980 and recent price shocks in 1999 and 2000. It not only serves as a foundation for the future energy saving requirements but also provides significant implications for policy response and environmental degradation (Brenton, 1997 and Galindo, 2005). Consequently, many studies such as Bentzen and Lngsled (1993), Pindyck (1979), Fiebig et al. (1987), Chan and Lee (1996),); Cooper (2003); Liu (2004) and Welsch and Ochsen (2005) have been conducted to indicate factors influencing energy consumption. Most of these studies use income and price elasticities estimates for policy analysis. Since price is considered as the major component of reform, price elasticities are vastly used in structuring policies (Narayan and Smyth, 2005).

Early in 1979, Pindyck used a pooled time series data for OECD countries to focus on the demand for energy. He revealed that energy prices and income had a significant impact on the energy consumption of domestic, transport and industrial sectors of both developed and developing countries. Using data of OECD countries Beenstock and Willcocks (1981) also provided similar evidence. In addition to price and income they found that technical progress also had a considerable impact on the demand for energy. Later in 1996, Chan and Lee showed that the degree of industrialization increased the demand for energy in case of China. Adams and Shachmurove (2000) also gave evidence of the importance of economic structure as a determinant of energy consumption. They found that industrialization and energy use are positively related in case of East Asian Countries. Studies by Fouquet et al. (1996), Hunt and Ninomiya (2005) and Rapanos and Polemis (2006) show that energy consumption is correlated with higher income as the growth of energy demand and GDP move in the similar trend. Medlock and Soligo (2001) also gave evidence that with the increase in per capita income consumers tend to raise the share of consumers budget spent on durables (air conditioners, refrigerators and automobiles) which make use of energy intensively. With the use of these durables the demand for energy not only increases in the residential sector but also in the commercial and transport sectors. Gately and Huntington (2002) analyzed the relationship of income and energy use of 96 countries during 1971 to 1997. They analyzed the asymmetric effects on the demand for energy by increasing and decreasing income and suggested that the income elasticity for energy is 0.5 for the OECD countries while for others it ranged between 0.5-1.0. They concluded that the non- OECD countries responded more to the increase in income in comparison to the decrease in income.

Studies also prove that energy consumption grows with the process of industrialization. Samoulidis and Mitropoulos (1984) showed evidence of positive influence of industrialization on energy consumption by using the value added by industries as a proxy of industrialization. Adams and Shachmurove (2008) also proved the positive relation of energy consumption and economy structure empirically using the share of industry in GDP as the degree of industrialization in the East Asian countries. Later Schafer (2005) examined the role of structural change in the energy consumption using eleven countries for the period of 1971-1998. She suggested that the structural changes causes changes in the sectoral shares of energy consumption. In addition to industrialization, a bulk of studies have concluded that energy consumption is positively related to urbanization in both single country and multi country analysis (Cole and Neumayer, 2004; Kaneko, 2010; Hossain, 2011; Al-mulali et al., 2012; Shahbaz et al., 2014).

On the other hand technological change was also found to be energy saving (Berndt et al. 1993, Popp, 2001, Lin, 2003 and Welsch and Ochsen, 2005). There are other studies (Brenton 1997, Pesaran et al. 2001, Holtedahl and Joutz 2004, Narayan and Smyth 2005, Vita et al., 2006, Yoo et al. 2007, Ziramba 2008 and Dilaver and Hunt 2011) which focus only on determinants of electricity consumption. Results of these studies showed that price elasticity was negative in case of electricity and the income elasticity was found to be positive in case of residential demand. Other studies have also analyzed the impact of institutional quality on energy consumption but the outcome of these studies remains inconclusive (Esty and Porter 2005). Some of these studies have reported a positive impact of democracy on energy consumption though provision of freedom and political rights regarding the use of natural resources (Barbier, 2015; Bernauer et al., 2012; Wirth, 2014; Cifor et al., 2015 and Chang and Wang, 2017). While, other studies are in support of a negative impact (Gallagher and Thacker, 2008) or no impact on energy use (Scruggs and Rivera, 2008).

However, in case of Pakistan very little analytical work has been done in this regard. Iqbal, (1983) analyzed the residential price and income elasticities for electricity and gas for the period 1960 to 1981 using OLS. The income elasticity was positive for both the energy goods, while the own price elasticity was found to be negative in case of gas. Later Siddiqui and Haq (1999) examined the demand function for gas, electricity and petroleum products for aggregate and disaggregate levels using OLS estimation technique. They concluded that in general energy consumption is income and price elastic.

There are other studies which focus on only one energy item i.e. electricity which use causality test and co integration in order to analyze the relation between economic growth and electricity use. For example, Aqeel and Butt (2001), Siddique (2004) and Lee (2005) concluded that the causality runs from energy consumption to GDP while, Khan and Ahmed (2010) predicted the causality to be unidirectional from economic activity to electricity use. Khan & Qayyum, (2009) examined the patterns of electricity demand over the period of 1970-2006. The income elasticity was found to be positive for all the groups while the price elasticity was negative. Similarly by using a Cobb-Douglas production function, Shahbaz, et al. (2012) investigated the relationship between GDP and energy demand during the period 1972-2011 and confirmed it to be positive. Nawaz, Iqbal & Anwar, (2013) checked for the linear as well as nonlinear electricity demand function for the period of 1971-2012 by applying a model of logistic smooth transition regression. They proved that a long run relationship exists between electricity consumption, its prices and GDP per capita. They further concluded that the electricity consumption is basically influenced by development. The nonlinear estimates showed that the demand for electricity is insensitive to any price change beyond the threshold level. Later in 2014, Javid & Qayyum, analyzed the relationship among electricity demand, its prices, real economic activity and underlying energy demand trend for aggregate as well as sectoral levels over the period of 1972-2010. The found that the nature of relationship among these variables was stochastic instead of linear and deterministic.

The literature on energy demand suggests that analyzing the factors of energy demand provides significant information for policy structuring and energy conservation. Hence, in order to design energy policies there is a significant need to analyze the demand functions for different energy products. However, the literature on energy demand in case of Pakistan only focuses electricity ignoring the other important components of energy i.e.

gas and petroleum products. Moreover, significant determinants like urbanization and institutional quality have been ignored in the literature on energy consumption. This chapter aims to fill the gap by analyzing the demand functions of three important energy components in order to understand why the energy pricing policy reforms have not been successful in increasing the efficient use of energy.

2.3.2 Literature Review on Energy Input and Substitution

There are three categories in the literature relating to the substitution of energy and non-energy inputs. The first category focuses on the substitution among factors like capital, labor and raw materials with energy (Berndt and Wood, 1975; Fuss, 1977; Caloghirou et al., 1997; Christopoulos, 2000, Christopolus; Tsionas, 2002 and Roy et al., 2006). The results for the substitution possibilities between energy and other factors like labor and capital are mixed. Early studies by Berndt and Wood (1975) found evidence that energy and capital are complements in case of United States. Fuss (1977) and Prywes (1986) are also in support of the complementarity of energy and capital. Other studies such as Caloghirou and Christopoulos (2000) and Christopoulos and Tsionas (2002) suggests that energy and capital are complements in case of Greece. On the other hand Pindyck (1979) found the opposite result analyzing 10 developed countries concluding that energy and capital are substitutes. The results of the research carried out by Truong (1985), Thompson and Taylor (1995) and Christopoulos (2000) also provide evidence in support of the substitutability of capital and energy.

The second category consists of studies that focus on inter fuel substitution among various type of energy products (Hall, 1986; Vlachou and Samouilidis, 1986; Taheri, 1994 and Jones, 1996). Hall (1986) estimated own price and cross price elasticities using annual observations of coal, electricity, gas and petroleum of seven countries of OECD over the years 1960-79. He found results in support of substitution possibility between gas and coal for France and United Kingdom. While the response of electricity to changes in the petroleum prices was found to be inelastic for Canada, Japan, Italy and U.S. Jones (1996) examined the industrial sector of the G-7[2] countries for inter fuel substitution. He used two dynamic models and gave evidence of substitution between oil and natural gas. He suggested that since the demand for oil is very elastic in these countries, a higher tax on oil would serve to very effective to reduce oil consumption and increase the usage of coal, gas and electricity.

Recent literature on inter fuel substitution shows that the elasticity of substitution among the energy products is positive (Bello et al., 2018; Considine, 2018; Suh 2016; Lin and Atsagli, 2017; Zhang et al., 2018; Sadaf et al., 2018; Arshad et al., 2018). Bello and Solarin (2020) analyzed the possibility of substitution among hydro power and other fossil fuels for the generation of electricity in Malaysia. They concluded that due to the positive substitution elasticity hydropower should be substituted for other fuels to reduce carbon emission. Lin and Abudu (2020) also showed that energy efficiency can be increased with the help of inter fuel substitution in case of Ghana.

While the third category is based on a two stage approach focusing on the substitution among energy fuels and non-energy factors. The earliest study on the two stage approach is by Fuss (1977) on Canadian manufacturing for the period of 1961 to 1971. He found considerable substitutability among fuels with positive cross price elasticities apart

[2] G7 countries are the largest industrialized countries consisting of Canada, France, Germany, Italy, Japan, the United Kingdom and the United States.

from motor gasoline and electricity. The demand for the factor inputs was found to be inelastic with possibilities of substitutability among the factor inputs. However, energy resulted as a compliment to capital. The substitution between aggregate energy and aggregate inputs was very low. Cho et al. (2004) also followed the two stage estimation methodology considering the feedback effect of changes in fuel prices. They explained how the changes in fuel prices will affect not only the inter fuel substitution but also the inter factor substitution. They also explained how inter factor substitution affects the inter fuel substitution through changes in aggregate energy consumption. Wesseh et al. (2013) showed that there are substitution possibilities between coal and capital and capital and electricity in case of Libya.

In case of Pakistan there have been a number of studies that focus on inter factor substitution for large scale manufacturing sector. Most of the studies are restricted to two inputs i.e. capital and labor. Some studies have extended the inputs by including energy and raw materials along with capital and labor. Khan (1989) and Khan and Rafiq (1993) have calculated the elasticities of substitution using a nested CES production function. They found evidence of capital labor substitution with high estimates of elasticity of substitution. Mahmood (1989) also found similar results suggesting possibilities of substitution between capital and labor. The evidence of capital labor substitution was also corroborated by Ahmad and Idrees (1999), Khan and Burki (1999) and Chaudry et al. (1999). However, Mahmood (1992) and Ahmad and Idrees (1999) reported changing patterns of substitution between energy and capital. Both studies found that till mid to late seventies energy and capital were compliments and became substitutes in the subsequent period. Lin and Ahmad (2016) also supported for the possibility of energy and non-energy substitution in Pakistan. Their results showed that non energy inputs had the highest elasticity of substitution in case of petroleum products. Later Khalid and Jalil (2019) focused on the inter fuel substitution and found that coal and natural gas had the highest degree of substitution. Their results also showed high responsiveness of hydroelectricity with positive output elasticity.

Hence, the literature on inter factor and inter fuel substitution shows that there are possibilities of substitution among different energy products. In the presence of energy shortages and rising fuel prices, the analysis on inter fuel substitution becomes significantly important for Pakistan. This chapter aims to contribute to the existing literature by analyzing the substitution possibilities among energy as well as non-energy products. This analysis will provide useful insights for policymakers as Pakistan is running short of energy reserves.

2.4 Theoretical Framework

The section of theoretical framework contains two subsections. The first section presents the model for the relationship between energy consumption and its determinants for different economic sectors. The theoretical framework for the inter fuel and inter factor substitution is presented in the second subsection.

2.4.1 Energy Consumption

The energy consumption is divided in two ways i.e. by different energy source (electricity, gas and petroleum products[3]) and by different user groups (household, industry, commercial and others). Following Kouris (1983), Bentzen and Engsted (1993), Plourde

[3] Motor Spirit, Furnace Oil, High Speed Diesel, light diesel oil and superior kerosene are included in the POL products.

and Ryan (1985), and Galindo (2005), the energy demand function have been derived from the Cobb-Douglas utility function:

$$U = N^{\alpha 1} B^{\alpha 2} \quad (2.1)$$

Where, N is energy consumption and B is consumption of other goods. With the incorporation of substitutes to the specific energy goods equation (2.1) becomes

$$N = N(E_i, S_i) = \exp(S_i^{\beta} E_i^{\gamma}) \quad (2.2)$$

Where, the subscript "i" is the ith energy good. Substituting equation (2.2) in (2.1), we get

$$U(B, N(E_i, S_i) \quad (2.3)$$

Which is subject to the following budget constraint

$$P_b B + P_{ei} E_i + P_s S = Y \quad (2.4)$$

Where, Pb, Pe, and Ps are the prices of non-energy goods, energy goods and energy substitutes, respectively. In order to analyze the energy demand the sub-utility function is maximized subject to the budget constraint given as:

$$P_{ei} E_i + P_s S = Y^* \quad (2.5)$$

Where, $Y^* = Y - P_b B,$ which shows the total expenditure on energy subgroup. After taking derivatives for specific energy goods, the energy consumption function for each category are given in the following subsections:

2.4.1.1 Electricity Consumption

Electricity consumption function is specified for each sector as:

$$lnEc_{it} = \alpha_0 + \alpha_1 lnP_{it}^{e} + \alpha_2 lnP_{jit} + \alpha_3\ lnY_t + \alpha_4 lnN_{it} + \alpha_5 lnUR_t + \alpha_6 lnIQ_t + \ \varepsilon_t \quad (2.6)$$

Where Ec_{it} is the electricity consumption function of sector "i" respectively, in period t. P_{it}^{e} is the price of electricity faced by each sector "i" and $P_{jit}$is the price of related substitutable energy sources like gas, furnace oil, kerosene oil etc. Y_t gives the total output (GDP). N_t is the number of users in each sector "i", $UR_t$is the urbanization rate, $IQ_t$is the institutional quality index and ε_t gives the error term. Due to the unavailability of data on price of appliances in time series form it was not included in the model.

2.4.1.2 Gas consumption

The consumption function of gas is specified in a similar manner for each sector

$$lnGc_{it} = \alpha_0 + \alpha_1 lnP_{it}^{g} + \alpha_2 lnP_{jit} + \alpha_3 lnY_t + \alpha_4 lnN_{it} + \alpha_5 lnUR_t + \alpha_6 lnIQ_t + \ \varepsilon_t (2.7)$$

Where Gc_{it} is the gas consumption functions sector "i" respectively, in period t. P_{it}^{g} is the price of gas faced by each sector "i" and $P_{jit}$is the price of related substitute energy sources like electricity in each sector. The gas price also includes the surcharge imposed by government. Y_t is gives the total output (GDP). I_t is the number of users in each sector i. N_t is the number of users in each sector "i", $UR_t$is the urbanization rate, $IQ_t$is the institutional quality index and $\varepsilon_t$gives the error term. The demand for gas and electricity is also affected by the price of appliances using these energy sources but since the data for this variable is not available it is not added in the demand function.

2.4.1.3 Petroleum Products consumption

The consumption analysis of each petroleum product (Motor spirit, High speed diesel, Low diesel oil, Kerosene oil and furnace oil) can be classified according to the consumption of its users. For instance the industry consumes more than 60% of furnace oil while the domestic sector consumes about 70% of kerosene is used by the domestic sector. Similarly the consumption of high speed diesel, low diesel oil and motor spirit is predominantly from the transport sector. The consumption function of the petroleum products are given accordingly

$$lnKc_{ht} = \alpha_0 + \alpha_1 lnP_{ht}^{k} + \alpha_2 lnP_{jht} + \alpha_3 lnY_t + \alpha_4 lnpop_t + \alpha_5 lnIQ_t + \varepsilon_t \qquad (2.8)$$

$$lnFOc_{it} = \alpha_0 + \alpha_1 lnP_{it}^{fo} + \alpha_2 lnP_{jit} + \alpha_3 lnY_t + \alpha_5 lnY_{it} + \alpha_6 lnIQ_t + \varepsilon_t \qquad (2.9)$$

$$lnHSDc_{rt} = \alpha_0 + \alpha_1 lnP_{rt}^{hsd} + \alpha_2 lnP_{jrt} + \alpha_3 lnY_{rt} + \alpha_4 lnBT_t + \alpha_5 lnIQ_t + \varepsilon_t \qquad (2.10)$$

$$lnLDOc_{rt} = \alpha_0 + \alpha_1 lnP_{rt}^{ldo} + \alpha_2 lnP_{jrt} + \alpha_3 lnY_{rt} + \alpha_4 lnBT_t + \alpha_5 lnIQ_t + \varepsilon_t \qquad (2.11)$$

$$lnMSc_{rt} = \alpha_0 + \alpha_1 lnP_{rt}^{ms} + \alpha_2 lnP_{jrt} + \alpha_3 lnY_{rt} + \alpha_4 lnC_t + \alpha_5 lnIQ_t + \varepsilon_t \qquad (2.12)$$

Where $Kc_{it}$is the Kerosene consumption by the household sector in period t. P_{ht}^{k} is the price of kerosene and $P_{jit}$is the price of related substitutable energy sources like electricity and gas for the residential sector. Y_t gives the total ouput (GDP) and pop stands for the population.

FOc_{it} is furnace oil consumption of the industrial sector. $P_{it}^{fo}$is the price of furnace oil and P_{jit} is the price of other related energy sources. $Y_{it}$is the value added by industry. Similarly$HSDc_{rt}$, $LDOc_{rt}$ *and* MSc_{rt} are the high speed diesel, low diesel oil and motor spirit consumptions respectively by the transport sector. P_{rt}^{i} is the price of the ith fuel and $Y_{rt}$is the value added by the transport sector. Since the consumption of these fuels is also affected by the number of vehicles hence the number of buses and trucks (BT) and the number of cars, taxis, motorcycles ($\mathrm{C_t}$)are also included. N_t is the number of users in each sector "i", $IQ_t$is the institutional quality index and $\varepsilon_t$gives the error term.

2.4.2 Energy Input and Substitution

In order to estimate the substitution possibilities between input factors studies such as Adeyemo et al., 2007, Ma et al., 2008 and Penphanussak and Wongsapai, 2008, have made use of the trans log cost given by Berndt and Christensen (1973). The trans log functional form is more flexible in the sense that it allows the elasticities of substitution to change according to the share of fuels. The cost function is given as:

$$C = (Pk, Pl, PE, PM, Q) \tag{2.13}$$

This cost function can be represented by a trans log cost function as:

$$lnC = \alpha_0 + \sum_{i=1}^{n} \alpha_1 lnP_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{m} \gamma_{ij} lnP_i lnP_j + \alpha_y lnY_i + \frac{1}{2}\gamma_{yy}(lnY)^2 + \sum_{i=1}^{n} lnP_i lnY \tag{2.14}$$

where i, j = 1… N are different inputs, C is total cost, Y is output and the P,'s are the prices of the factor inputs. After solving for cost minimizing input demand equations the elasticity for substitution can be obtained for different factor inputs.

Following Wesseh et al., (2013), tran log production function has been used as the data for factor prices is not available in case of Pakistan. The trans log production function is given as:

$$Y_t = f(K_t, L_t, P_t, G_t, E_t) \tag{2.15}$$

Where Yt represents output, Kt capital stock, Lt labor, Pt petroleum, Gt natural gas and E_t electricity consumption. The trans-log production function is given as:

$$\ln Y_t = \alpha + \beta_k \ln K_t + \beta_l \ln L_t + \beta_p \ln P_t + \beta_g \ln G_t + \beta_e \ln E_t + \beta_{kl} \ln K_t \ln L_t +$$
$$\beta_{kp} \ln K_t \ln P_t + \beta_{kg} \ln K_t \ln G_t + \beta_{ke} \ln K_t E_t +$$

$$+\beta_{lp}\ln L_t \ln P_t + \beta_{lg}\ln L_t \ln G_t + \beta_{le}\ln L_t E_t + + \beta_{pg}\ln P_t \ln G_t + \beta_{pe}\ln P_t E_t +$$

$$+\beta_{kk}(\ln K_t)^2 + \beta_{ll}(\ln L_t)^2 + \beta_{pp}(\ln P_t)^2 + \beta_{gg}(\ln G_t)^2 + \beta_{ee}(\ln E_t)^2 \tag{2.16}$$

Differentiating equation (2.16) with respect to the natural log of Kt, Lt, Pt, Gt and Et, the output elasticity is generated with respect to the input used:

$$\varphi K = \frac{dY/_Y}{dK/_K} = \frac{d\ln Y_t}{d\ln K_t} = \beta_k + \beta_{kl}\ln L_t + \beta_{kp}\ln P_t + \beta_{kg}\ln G_t + 2\beta_{kk}\ln K_t \tag{2.17}$$

$$\varphi L = \frac{dY/_Y}{dL/_L} = \frac{d\ln Y_t}{d\ln L_t} = \beta_L + \beta_{kl}\ln K_t + \beta_{lp}\ln P_t + \beta_{lg}\ln G_t + 2\beta_{ll}\ln L_t \tag{2.18}$$

$$\varphi P = \frac{dY/_Y}{dP/_P} = \frac{d\ln Y_t}{d\ln P_t} = \beta_P + \beta_{kP}\ln K_t + \beta_{lp}\ln L_t + \beta_{Pg}\ln G_t + 2\beta_{PP}\ln P_t \tag{2.19}$$

$$\varphi G = \frac{dY/_Y}{dG/_G} = \frac{d\ln Y_t}{d\ln G_t} = \beta_G + \beta_{kG}\ln K_t + \beta_{lG}\ln L_t + \beta_{Pg}\ln P_t + 2\beta_{GG}\ln G_t \tag{2.20}$$

$$\varphi E = \frac{dY/_Y}{dE/_E} = \frac{d\ln Y_t}{d\ln E_t} = \beta_E + \beta_{ke}\ln K_t + \beta_{le}\ln L_t + \beta_{Pe}\ln P_t + 2\beta_{ee}\ln E_t \tag{2.21}$$

The elasticity of substitution measures percent change in one input factor due to the percent change in marginal rate of technical substitution. In other words it illustrates how the substitution among input factors changes with the change in the price of one factor input. The elasticity between labor and capital is given as:

$$\sigma_{KL} = \frac{d(\frac{K}{L})}{(\frac{K}{L})}\left[\frac{d(\frac{MPP_L}{MPP_K})}{(\frac{MPP_L}{MPP_K})}\right]^{-1} = \frac{d(\frac{K}{L})}{d(\frac{MPP_L}{MPP_K})} \cdot \frac{(\frac{MPP_l}{MPP_K})}{(\frac{K}{L})} \tag{2.22}$$

MPPK is the marginal physical productivity of capital and MPPL is the marginal productivity of labor.

$$\frac{MPP_l}{MPP_K} = \frac{\partial Y/_{\partial L}}{\partial Y/_{\partial K}} = \frac{\varphi_L}{\varphi_K} \cdot \frac{K}{L} \tag{2.23}$$

Combining (2.22) and (2.23), we get equation (2.24)

$$\sigma_{KL} = \frac{d(\frac{K}{L})}{d(\frac{MPP_l}{MPP_K})} \cdot \frac{\varphi_L}{\varphi_K} = \frac{\varphi_L}{\varphi_K} \cdot \left[\frac{d(\frac{MPP_L}{MPP_K})}{(\frac{MPP_l}{MPP_K})}\right]^{-1} = \frac{\varphi_L}{\varphi_K} \cdot \left[\frac{d(\frac{\varphi_L K}{\varphi_K L})}{d(\frac{K}{L})}\right]^{-1} \tag{2.24}$$

We also know that

$$\frac{d(\frac{\varphi_L K}{\varphi_K L})}{d(\frac{K}{L})} = \frac{\varphi_L}{\varphi_K} + \frac{K}{L} \cdot \frac{d(\frac{\varphi_L}{\varphi_K})}{d(\frac{K}{L})} \tag{2.25}$$

$$d\left(\frac{\varphi_L}{\varphi_K}\right) = -\frac{\varphi_L}{\varphi_K} . d\varphi_K + \frac{1}{\varphi_K} d\varphi_L \tag{2.26}$$

$$d\left(\frac{K}{L}\right) = -\frac{K}{L^2} . dL + \frac{1}{L} dK \tag{2.27}$$

Putting (2.25) to (2.26) and (2.27) together we get equation (2.28) which gives substitution elasticity between capital and labor.

$$\sigma_{KL} = \left[1 + \left[-\beta_{kl} + \frac{\varphi_K}{\varphi_L} . \beta_{ll}\right] (-\varphi_K + \varphi_L)^{-1}\right]^{-1} \tag{2.28}$$

Similarly we get substitution elasticities between other input pairs;

$$\sigma_{KP} = \left[1 + \left[-\beta_{kP} + \frac{\varphi_K}{\varphi_P} . \beta_{PP}\right] (-\varphi_K + \varphi_P)^{-1}\right]^{-1} \tag{2.29}$$

$$\sigma_{KG} = \left[1 + \left[-\beta_{kG} + \frac{\varphi_K}{\varphi_G} . \beta_{GG}\right] (-\varphi_K + \varphi_G)^{-1}\right]^{-1} \tag{2.30}$$

$$\sigma_{KE} = \left[1 + \left[-\beta_{ke} + \frac{\varphi_K}{\varphi_e} . \beta_{ee}\right] (-\varphi_K + \varphi_e)^{-1}\right]^{-1} \tag{2.31}$$

$$\sigma_{LP} = \left[1 + \left[-\beta_{LP} + \frac{\varphi_L}{\varphi_P} . \beta_{PP}\right] (-\varphi_L + \varphi_P)^{-1}\right]^{-1} \tag{2.32}$$

$$\sigma_{LG} = \left[1 + \left[-\beta_{LG} + \frac{\varphi_L}{\varphi_G} . \beta_{GG}\right] (-\varphi_L + \varphi_G)^{-1}\right]^{-1} \tag{2.33}$$

$$\sigma_{Le} = \left[1 + \left[-\beta_{Le} + \frac{\varphi_L}{\varphi_e}.\beta_{ee}\right](-\varphi_L + \varphi_e)^{-1}\right]^{-1} \quad (2.34)$$

$$\sigma_{PG} = \left[1 + \left[-\beta_{PG} + \frac{\varphi_P}{\varphi_G}.\beta_{GG}\right](-\varphi_P + \varphi_G)^{-1}\right]^{-1} \quad (2.35)$$

$$\sigma_{Pe} = \left[1 + \left[-\beta_{Pe} + \frac{\varphi_P}{\varphi_e}.\beta_{ee}\right](-\varphi_P + \varphi_e)^{-1}\right]^{-1} \quad (2.36)$$

$$\sigma_{Ge} = \left[1 + \left[-\beta_{GE} + \frac{\varphi_G}{\varphi_E}.\beta_{eE}\right](-\varphi_G + \varphi_E)^{-1}\right]^{-1} \quad (2.38)$$

2.5. Data and Econometric Methodology

This section is divided into three subsections. The data and variables used in this chapter are discussed in first subsection and the second and third subsections consist of the explanation econometric methodology used.

2.5.1 Data

This study uses annual data for the period 1984-2019 collected from different sources to estimate the demand functions of each energy item. Data for Gross domestic product (GDP) is used from Pakistan Economic Survey, data for consumption of energy sources and their prices is taken from Energy year book (various issues). Following Ahlborg et al., (2015), the institutional quality index has been constructed by taking the average of 6 variables from the ICRG data that best fit with our theoretical perceptions about the role of institutes in provision of energy goods. We have included (1) Law and order, (2) Corruption, (3) Government Stability, (4) Investment Profile, (5) Democratic accountability and (6) Bureaucratic Quality. The data for urbanization has been taken from WDI which measures urbanization as percentage of total population.

While for estimating the substitution possibilities the data on GDP, labor, capital stock, oil, electricity, natural gas consumption, and prices of various energy sources in

Pakistan for the period 1980-2019 is taken from various issues of Energy Year Book (various issues), National Electric Power Regulatory Authority (NEPRA) and Pakistan Economic Survey (various issues)[4]. The data on the gross capital of Pakistan's economy has been measured by capital stock through the Perpetual Inventory Method as given in the following equation:

$$K_t = K_{t-1} + (1 - \delta) + I_t \tag{2.32}$$

In this equation Kt is the capital stock in year t, Kt−1 represents the capital stock of t-1, δ and It represents the depreciation rate and the gross domestic investment in year t respectively. The initial capital stock is represented as:

$$K_0 = \frac{I_0}{g+\delta} \tag{2.33}$$

Where K_0 is the initial capital stock, Io is the initial investment and g gives the growth rate of investment. Table 2.3 summarizes the variables used and displays how each variable is defined as well as some important descriptive statistics.

2.5.2. Energy consumption

To examine the relationship between energy consumption and its determinants (energy prices, GDP, number of users etc.) this study has employed bound testing approach to cointegration (ARDL approach) developed by Pesaran et al., (2001). The ARDL cointegration approach has been selected as it has several advantages in comparison with other cointegration methods such as Engle and Granger (1987), Johansen (1988) and ordinary least square procedures as used in the previous studies of energy demand in case of Pakistan. First the ARDL procedure has the advantage of being independent of

[4] Both are published by government of Pakistan.

classification of variables into I(0) and I(1) and there is no need of pre testing of variable for unit root. A single reduced form equation is employed to estimate long run relationship instead of a system of equations as used in the conventional cointegration procedures (Ozturk & Acaravci, 2010). Secondly, ARDL modelling does not need large data samples for validity as required by Johansen cointegration techniques. It can test for cointegration with consistent parameters even when the data sample is small. Estimates the have used Engle and Granger (1987) and Johansen (1988) methods of cointegration are not robust for small sample sizes (Mah, 2000). Furthermore, ARDL allows for different optimal lags for variables which is not possible while using conventional cointegration procedures (Narayan, & Smyth, 2005).

There are two steps in the bound testing approach. In the first stage the long run relationship is established between the variables of the consumption function. While in the next stage the long run and short run coefficients are estimated provided that cointegration exists (Pesaren et al., 2001).

Table 2.3: Descriptive statistics for dependent and independent variables.

Variables	Definitions	Mean	Std. dev.	Min	Max
Dependent variable					
EC (H)	Electricity Consumption by residential sector (KW)	14.46	0.52	13.34	16.04
EC (C)	Electricity Consumption by commercial sector (KW)	12.66	0.37	12.06	13.18
EC (I)	Electricity Consumption by industrial sector (KW)	14.38	0.59	13.81	16.11
EC (A)	Electricity Consumption by agriculture sector (KW)	13.34	0.29	12.81	14.10
GC (H)	Gas Consumption by residential sector (MMbtu)	14.60	0.43	13.60	14.70
GC (C)	Gas Consumption by commercial sector(MMbtu)	12.97	0.53	12.08	13.76
GC (I)	Gas Consumption by industrial sector (MMbtu)	14.96	0.30	14.19	15.83
Sk	Consumption of super kerosene oil (Ltrs)	12.13	0.29	11.62	12.59
FO	Consumption of furnace oil (Ltrs)	13.74	0.57	12.19	14.56
MS	Consumption of motor spirit (Ltrs)	13.91	0.44	13.13	15.06
HSD	Consumption of high speed diesel (Ltrs)	15.38	0.49	14.34	15.88
LDO	Consumption of low diesel oil (Ltrs)	6.71	0.53	5.87	7.57
Independent Variables					

Y	Gross domestic product	15.45	0.47	14.58	16.18
IQ	Institutional Quality Index	3.94	0.12	2.84	4.08
UR	Urban population as a percentage of total population	3.47	0.04	3.58	3.34
NEH	No. of electricity users in the residential sector	15.97	0.55	14.93	16.73
NEI	No. of electricity users in the industrial sector	12.13	0.29	11.62	12.59
NEC	No. of electricity users in the commercial sector	14.37	0.20	14.19	14.74
NEA	No. of electricity users in the agriculture sector	12.07	0.32	11.55	12.60
NGH	No. of gas users in the residential sector	15.06	0.39	14.65	15.84
NGI	No. of gas users in the industrial sector	8.65	0.34	8.37	9.28
NGC	No. of gas users in the commercial sector	10.96	0.18	10.72	11.30
TR	No. of cars, taxis, motorcycles	14.06	0.57	12.93	15.00
C	No. of cars, taxis, motorcycles	12.44	0.45	11.61	13.09
PeA	Price of electricity for agriculture sector (Rs/KW)	0.44	0.69	0.60	0.45
PeC	Price of electricity for commercial sector (Rs/KW)	0.89	0.57	0.25	1.06
PeH	Price of electricity for residential sector (Rs/KW)	0.49	0.54	0.42	0.93
PeI	Price of electricity for industrial sector (Rs/KW)	0.53	0.12	0..55	0.70
PFO	Price of electricity of furnace oil (Rs/Ltr)	2.13	0.50	2.02	2.63

PgC	Price of gas for commercial sector(Rs/MMbtu)	4.84	0.14	3.93	5.02
PgH	Price of gas for residential sector(Rs/MMbtu)	4.40	0.13	3.38	4.51
PgI	Price of gas for industrial sector (Rs/MMbtu)	4.80	0.29	3.37	5.40
PHSD	Price of high speed diesel oil (Rs/Ltr)	2.62	0.19	2.11	2.72
PLDO	Price of low diesel oil (Rs/Ltr)	2.42	0.24	2.01	2.58
PMS	Price of motor spirit (Rs/Ltr)	3.06	0.37	2.98	3.61
PSK	Price of super kerosene oil (Rs/Ltr)	2.51	0.26	2.11	2.65

The ARDL procedure to cointergration is explained as under:

Consider a vector of two variable Zt where $z_t = (y_t, x_t')'$, $y_t$is the dependent variable and xt is a vector of regressors. The data generating process of zt is p-order vector autoregression.

$$\Delta y_t = \beta_0 + \beta_1 t + \pi_{yy} y_{t-1} + \pi_{xx} x_{t-1} + \sum_{i=1}^{p} \vartheta_i \Delta y_{t-i} + \sum_{j=0}^{q} \emptyset_j' \Delta x_{t-j} + \theta w_t + u_t \quad (2.34)$$

Here, $\pi_{yy}$and $\pi_{xx}$are long run multipliers, $\beta_0$is the drift, t is the time trend and $w_t$is a vector of exogenous components. Lagged values of $\Delta y_t$and Δx_t are also used to model the short run dynamic structure. The bound testing procedure entails the following hypothesis

$$H_0, \pi_{yy} = 0, \;\; \pi_{yx.x} = 0'$$

$H_0, \pi_{yy} \neq 0, \;\; \pi_{yx.x} \neq 0'$or ,$\pi_{yy} \neq 0, \;\; \pi_{yx.x} = 0' \; or \; \pi_{yy} = 0, \;\; \pi_{yx.x} \neq 0'$

These hypothesis are estimated using the F statistic. If the F stat is below the lower bound than the null of no cointegration cannot be rejected and if it is greater than the upper bound the null is rejected. The energy demand literature mostly (implicitly) assumes that explanatory variables used in equation (1) to equation (7) are exogenous. However, in the presence of endogeneity an adequate number of lagged values of these variables have to be included (Bentzen and Engsted, 1999).

2.5.3 Inter factor and inter fuel substitution

Using the trans log production function, a large number of explanatory variables are estimated. There are high chances of presence of multicollinearity by using the ordinary least square (OLS) due to the linear association among the explanatory variables. It will not only increase the variance of the estimates but also make them inefficient. To avoid the threat of multicollinearity, the linear relationship has been examined in the explanatory variable (Appendix A2), following Lin and Ahmad, (2016). The results of Table A2., show that there is high correlation present among the explanatory variables. In such a case applying OLS technique will give biased results. In order to obtain efficient estimates the ridge regression has been utilized which is based on the linear regression equation given as:

$$Y = \alpha + \beta^T X \tag{2.35}$$

In order to obtain the estimates of $\beta_i (i = 1,2,3 \ldots m)$, the regression equation is modified as:

$$Y = X\beta + \varepsilon \tag{2.36}$$

Here X is based on sample data which by assumption is symmetric positive definite. The error vector is assumed to be normally distributed $(0,\sigma^2 I_n)$. The OLS unbiased estimate of $\beta$is then given as:

$$\beta = (X^T X)^{-1} X^T Y \tag{2.37}$$

Where the correlation matrix is given by R=$X^T X$. While the variance-covariance matrix is given as Var$(\beta) = \sigma^2 R^{-1}$. By expansion we get,

Var$(b_j) = r^{jj} = \frac{1}{1-R_j^2}$

(2.38)

Where R is obtained by regressing Xj on other explanatory variables. Ridge regression has been used in recent literature in order to solve the problem of multicollinearity. It adds a value k (which is assumed to be bounded above zero) to the diagonal elements of the correlation matrix which are in a form of ridge and is given as:

$$\bar{\beta} = (R + kI)^{-1}X^{T}Y \tag{2.39}$$

Where k=0,1,2…n. k mostly lies between 0 to 1.

2.6. Empirical Results

This section is broadly divided into two main subsections according to the objectives of the chapter. In the first part, the results of the energy consumption by sectors are discussed. While the second subsection discusses the results substitution possibilities among factors and energy.

2.6.1 Energy Consumption

This subsection is further divided according to the energy sources. The first subsection gives the results for electricity consumption. The second subsection gives the results for natural gas consumption while the results for the petroleum products consumption is given in the third subsection.

2.6.1.1 Electricity consumption

Before applying the ARDL model, the unit root test has been applied to check the stationarity of the variables using Ng and Perron (2001). The results are reported in the appendix (Table A3). The results show that most of the variables are non-stationary at level as the P-value is insignificant even at 10% significance level. However, at first difference all of the variables turn out to be stationary. In the first step we tested for the existence of long run relationship in eq (1) for electricity consumption. The maximum number of lags were set equal to 2 in the ARDL model for all the sectors. The computed F stat are reported in Table 2.4.

Table 2.4: Results of the Bounds Test for cointegration

Electricity consumption	**Variables included**	**F-statistic**
Household	$Ec_{Ht}, P^{e}_{Ht}, P_{Hjt}, Y_t, UR_t, N_{Ht}, , IQ_t$	12.08*
Industry	$Ec_{It}, P^{e}_{It}, P_{Ijt}, Y_t, Y_{it}, N_{it}, IQ_t$	7.80*
Commercial	$Ec_{ct}, P^{e}_{ct}, P_{cjt}, Y_t, Y_{ct}, N_{it}, IQ_t$	6.77*
Agriculture	$Ec_{At}, P^{e}_{At}, P_{Ajt}, Y_t, Y_{At}, N_{At}, IQ_t$	9.86*

Note: Critical values are given in Pesaran et al. (2001).

* Indicates significance at the 1 percent level

Table 2.4 shows that the computed F-statistics is greater than the upper bound of the critical values, giving evidence of cointegration among the variables of the household, industrial, commercial and agriculture sectors. Now equation 2.1 was further estimated by using the following ARDL (m,n,p,q,r) specification.

$$lnEc_{it} = \alpha_0 + \alpha_1 \sum_{i=1}^{m} lnEc_{t-i} + \sum_{i=0}^{n} \alpha_2 \; lnY_{t-i} + \sum_{i=0}^{p} \alpha_3 lnP^{e}_{t-i} + \sum_{i=0}^{q} \alpha_4 lnP^{j}_{t-i} + \sum_{i=0}^{r} \alpha_5 lnYi_{t-i} + \sum_{i=0}^{s} \alpha_6 lnICT_{t-i} + \sum_{i=0}^{t} \alpha_7 lnIQ_{t-i} + \varepsilon_t \qquad (2.38)$$

For each sector (i) a maximum of lag 2 was used based on minimizing SBC criterion. The empirical results obtained for each of the sector for the long run are reported in Table 2.5. while Table 2.6 gives the results for short run.

The results show the income elasticity for all the sectors is positive and statistically significant. The own price effect is negative and statistically significant for all sectors. The coefficient of own price effect (in absolute terms) is bigger for the residential sector as compared to other sectors. The price effect of natural gas is statistically insignificant while in case of kerosene oil the price effect is positive and statistically significant. These results imply that kerosene oil is used as a substitute for electricity in case of residential sector.

The impact of number of consumer on electricity demand is positive and statistically significant. While, the impact of income is positive and statistically significant in the short run. The estimates of own price effect and cross price effect (kerosene oil) have similar signs as of the long run estimates, however they are smaller in magnitude and are statistically significant. The number of users is positive but has an insignificant impact in the short run. This means that in case of domestic sector the key factors determining electricity consumption are electricity price, kerosene oil price and number of users.

Table 2.5: Estimated long-run coefficients

Dependent variable	**Regressor**	**Coefficient**	**Standard Error**
EC(H)	Y	0.22***	0.08
	PeH	-0.98**	0.43
	PgH	0.08	0.21
	Pfo	-0.06	0.04
	Psk	0.64**	0.30
	IQ	1.56***	0.22
	UR	1.41**	0.56
	NH	1.29**	0.49
EC(C)	Y	0.47***	0.16
	PeC	-0.38**	0.17
	PgC	1.04	0.67
	Pfo	0.01	0.05
	IQ	0.96***	0.16
	Yi	0.33**	0.15
	NC	3.35***	0.85
EC (I)	GDP	0.67***	0.26
	PeI	-2.36*	1.16
	Pfo	-0.80***	0.23
	PgI	-0.16	0.11
	IQ	0.58**	0.21
	UR	1.23***	0.29
	NI	4.79**	1.81
EC(A)	GDP	4.81**	2.24
	PeA	-0.12	0.08
	IQ	1.4***	0.38
	NA	3.57*	1.96

In case of the industrial sector, the price effect is negative and statistically significant though its value is quite small. The cross price effect for natural gas and furnace oil are statistically insignificant both in the short run and the long run. The impact of number of consumers is positive and significant but is smaller in magnitude as compared to the commercial and agriculture sectors. While, in case of commercial sector the income elasticity is positive and statistically significant. The price elasticity is negative and statistically significant, however it has a very small magnitude. This means that for the commercial sector electricity demand is relatively inelastic and smaller in magnitude than the rest of the sectors.

Table 2.6: Error-correction representation for the selected ARDL model

Dependent variable	Regressor	Coefficient	Standard Error
ΔEC(H)	D(EH(-1))	0.38**	0.18
	D(Y)	0.48	1.51
	D(Y(-1))	0.16	0.09
	D(PeH)	-0.17**	0.08
	D(PgH)	0.07	0.18
	D(Pfo)	-0.05	0.04
	D(Psk)	0.53*	0.27
	D(IQ)	0.88**	0.31
	D(IQ(-1))	0.86***	0.28
	D(UR)	0.62**	0.23
	D(NH)	0.27	0.53
	CointEq(-1)	-0.82	0.23
ΔEC(C)	D(Y)	1.41	1.05
	D(PeC)	-0.20***	0.05
	D(PgC)	-0.04	0.19
	D(PgC(-1))	-0.58	0.48
	D(Pfo)	0.003	0.02
	D(IQ)	0.10	0.27
	D(Yc)	0.17***	0.05
	D(Yc(-1))	0.01	0.04
	D(NC)	1.78***	0.35
	CointEq(-1)	-0.53***	0.15
ΔEC(I)	D(Y)	0.58***	0.23
	D(Y(-1))	0.32**	0.11
	D(PeI)	-0.39***	0.05
	D(PeI(-1))	-1.85**	0.70
	D(Pfo)	0.22	0.15
	D(Pfo(-1))	0.97**	0.42
	D(PgI)	-0.18	0.12
	D(IQ)	1.23***	0.21
	D(IQ(-1))	0.58**	0.43
	D(Yi)	0.28**	0.12
	D(NI)	0.74***	0.14
	CointEq(-1)	-0.66***	0.11
ΔEC(A)	D(EA(-1))	0.27	0.17
	D(Y)	0.28*	0.13
	D(GDP(-1))	2.54	2.69
	D(PeA)	-0.77*	0.36
	D(PeA(-1))	-0.36	0.27
	D(IQ)	0.04	0.18
	D(Ya)	0.24***	0.23
	D(Ya(-1))	0.26**	0.08
	D(NA)	3.04*	1.64
	D(NA(-1))	0.47	1.40
	CointEq(-1)	-0.57**	0.21

Note: *Statistical significance at 10% level, **Statistical significance at 5% level, ***Statistical significance at 1% level

The number of consumers is positive and statically significant in the long as well as the short run. For the agricultural sector the income effect is positive showing an increase in income would raise the consumption of electricity. The price effect is negative but insignificant. These results coincide with the findings of Siddiqui (2004) and Qayyum (2014). The reason for insignificant price effect could be the subsidized prices for the agricultural sector. Moreover the consumption of the agriculture sector is far less than the other sector. The price effect is significant in the short run but with a very small magnitude showing relatively inelastic demand. The results for the institutional quality index are in line with our theoretical expectations have statistically significant positive values for all the sectors in the long run. These results indicate consistency with the perception that if the politicians are able to implement large electrification projects, the electricity consumption is more likely to increase.

2.6.1.2 Gas consumption

In the first step we tested for the existence of long run relationship in eq (2) for gas consumption. The maximum number of lags were set equal to 2 in the ARDL model for all the sectors. The computed F stat are reported in Table 2.7.

Table 2.7: Results of the Bounds Test for cointegration

Gas consumption	**Variables included**	**F-statistic**
Household	$Gc_{Ht}, P_{Ht}^{g}, P_{Ht}^{j}, Y_t, UR_t, IQ_t, N_{ht}$	8.61*
Industry	$Gc_{It}, P_{It}^{g}, P_{It}^{j}, Y_t, N_{it}, Y_{it}, IQ_t$	7.99*
Commercial	$Gc_{ct}, P_{ct}^{g}, P_{Ct}^{j}, Y_t, N_{ct}, Y_{ct}, IQ_t$	6.16*

* Indicates significant at the 1 percent level

In each model the computed $F_{EC}(.)$ is higher than the upper bound critical value. Thus the null hypothesis of no cointegration cannot be accepted. Now equation 2.2 was further estimated by using the following ARDL (m,n,p,q,r) specification.

$$lnGc_{it} = \alpha_0 + \alpha_1 \sum_{i=1}^{m} lnGc_{t-i} + \sum_{i=0}^{n} \alpha_2 \; lnY_{t-i} + \sum_{i=0}^{p} \alpha_3 lnP_{t-i}^{g} + \sum_{i=0}^{q} \alpha_4 lnP_{t-i}^{j} + \sum_{i=0}^{r} \alpha_5 lnN_{t-i} + \sum_{i=0}^{r} \alpha_6 lnYi_{t-i} + \sum_{i=0}^{t} \alpha_7 lnIQ_{t-i} + \varepsilon_t \qquad (2.39)$$

For each sector (i) a maximum of lag 2 was used based on minimizing SBC criterion. The empirical results obtained for each of the sector for the long run are reported in table 2.8. While, Table 2.9 gives the results for short run.

Table 2.8: Estimated long-run coefficients

Dependent variable	Regressor	Coefficient	Standard Error
GC(H)	Y	1.37***	0.34
	PgH	-0.24**	0.11
	PeH	0.75	0.46
	Psk	0.39**	0.16
	IQ	0.24***	0.03
	UR	1.77***	0.57
	NH	2.07**	0.79
GC(C)	Y	0.79***	0.08
	PgC	-0.02*	0.01
	PeC	0.15***	0.05
	Pfo	-0.06***	0.02
	IQ	0.78*	0.49
	Yc	0.59**	0.23
	NC	0.21	0.19
GC(I)	GDP	5.00***	0.89
	PgI	-0.63***	0.08
	PeI	0.25***	0.05
	Pfo	-0.44***	0.08
	IQ	0.54	0.53
	Yi	0.15***	0.04
	NI	3.24***	0.80

Note: *Statistical significance at 10% level, **Statistical significance at 5% level, ***Statistical significance at 1% level

In case of the domestic sector the income elasticity is positive and the price elasticity is statistically significant but the magnitude shows that gas consumption is relatively price inelastic. In the short run the own price elasticity is negative but negligible.

The cross price elasticity for electricity is insignificant which confirms out earlier result for electricity. The cross price effect for kerosene oil is positive and significant which shows that kerosene oil is a substitute for gas for the domestic sector. This finding is similar to that of Siddiqui (2004) as kerosene oil is used as a substitute for gas for cooking and lighting purposes. The number of consumers exert a positive impact on the gas consumption both in the long and short run, however the magnitude is very small in the short run.

Table. 2.9: Short-run Error-Correction Model

Error-correction representation for the selected ARDL model			
Dependent variable	Regressor	Coefficient	Standard Error
ΔGC(H)	D(Y)	1.37***	0.33
	D(PgH)	-0.24*	0.09
	D(PeH)	0.10	0.47
	D(Psk)	0.33**	0.13
	D(IQ)	0.26**	0.08
	D(UR)	0.24*	0.11
	D(NH)	0.24***	0.03
	CointEq(-1)	-0.57**	0.21
ΔGC(C)	D(Y)	0.41**	0.17
	D(PgC)	-0.01**	0.00
	D(PeC)	0.08*	0.04
	D(Pfo)	-0.03***	0.01
	D(IQ)	0.10***	0.03
	D(Yc)	0.13***	0.03
	D(NC)	0.11	0.06
	CointEq(-1)	-0.52**	0.23
ΔGC(I)	D(Y)	1.27***	0.08
	D(GDP(-1))	1.23***	0.16
	D(PgI)	-0.02***	0.01
	D(PeI)	0.04	0.19
	D(Pfo)	-0.02***	0.00
	D(IQ)	0.07	0.06
	D(IQ(-1))	0.21**	0.08
	D(Yi)	0.82***	0.25
	D(NI)	0.14***	0.00
	CointEq(-1)	-0.04**	0.01

Note: *Statistical significance at 10% level, **Statistical significance at 5% level, ***Statistical significance at 1% level

For the industrial sector the income effect has the expected positive sign. The price elasticity is negative and significant in both the long and short run. However, the magnitude of price effect is very small showing that the price effect of gas consumption is relatively inelastic in case of industrial sector. The price effect of electricity is positive and statistically significant while in case of petroleum products, such as furnace oil, it is significantly negative. These results suggest that natural gas may substitute electricity while furnace oil complements electricity. The cross price effect of electricity is insignificant in the short run while cross price effect of furnace oil is negative and significant. Whereas, the gas consumption of the commercial sector is positively related to income and number of users. The price elasticity has the expected sign both in long and short run but the magnitude is very small in case of short run. The institutional quality index is significant for all the sectors in the long run, which coincides with the earlier findings for electricity showing that with the increase in provision of natural gas by the government projects, the gas consumption increases. The value added also shows significant results for all the sectors. These results are in accordance to the previous studies on energy demand (Siddiqui, 2004 and Iqbal, 1983) which conclude high income effect and low price effect for natural gas.

2.6.1.3 Petroleum Products Consumption

We tested for the existence of long run relationship for petroleum products consumption. The maximum number of lags were set equal to 2 in the ARDL model for all the sectors i.e. households, industrial and transport sector using minimum values of SBC. The computed F stat are reported in Table 2.10. In each model the computed $F_{GC}(.)$ is higher than the upper bound critical value. Thus the null hypothesis of no cointegration cannot be accepted in each model.

Table 2.10: Results of the Bounds Test for cointegration

Petroleum Products Consumption	Variables included	F-statistic
Kerosene oil	$SKc_{Ht}, P_{Ht}^{sk}, P_{Ht}^{j}, Y_t, Pop_t, IQ_t$	4.01**
Furnace oil	$FOc_{It}, P_{It}^{fo}, P_{It}^{j}, Y_t, Y_{It}, IQ_t$	3.75***
High speed diesel	$HSDc_{Tt}, P_{Tt}^{hsd}, P_{Tt}^{j}, Y_t, Y_{Tt}, TR_t, IQ$	6.26*
Low diesel oil	$LDOc_{Tt}, P_{Tt}^{ldo}, P_{Tt}^{j}, Y_t, Y_{Tt}, TR, IQ_t$	7.36*
Motor spirit	$MSc_{Tt}, P_{Tt}^{ms}, P_{Tt}^{j}, Y_t, Y_{Tt}, C, IQ_t$	49.28*

Now equations 2.3 to 2.7 was further estimated by using the following ARDL (m,n,p,q,r) specification.

$$lnPc_{it} = \alpha_0 + \alpha_1 \sum_{i=1}^{m} lnPc_{t-i} + \sum_{i=0}^{n} \alpha_2\, lnY_{t-i} + \sum_{i=0}^{p} \alpha_3 lnP_{t-i}^{p} + \sum_{i=0}^{q} \alpha_4 lnP_{t-i}^{j} + \sum_{i=0}^{r} \alpha_5 lnYi_{t-i} + \sum_{i=0}^{t} \alpha_6 lnIQ_{t-i} + \varepsilon_t \quad (2.40)$$

For each sector (i) a maximum of lag 2 was used based on minimizing SBC criterion. The empirical results obtained for each of the sector for the long run in Table 2.11. While, Table 2.12 gives the results for short run.

Results show that the income effect is positive for all of the petroleum products and statistically significant indicating that with the increase in income their consumption will also increase. The own price effect is negative and significant in case of all the petroleum products. The number of vehicle has a positive impact on the consumption of petroleum products. In case of cross price elasticities the results match our previous findings of kerosene being a substitute for electricity and natural gas.

Table 2.11: Long-run Coefficients

Dependent variable	Regressor	Coefficient	Standard Error
SK	Y	0.22**	0.08
	Psk	-0.83***	0.20
	PgH	0.95*	0.52
	Psk	0.29**	0.04
	IQ	0.27*	0.13
	Pop	0.81***	0.16
FO	Y	1.09**	0.40
	Pfo	-0.49***	0.14
	Phsd	1.08747	1.01
	IQ	0.42**	0.12
	Yi	0.32**	0.15
	IND	6.31**	2.72
HSD	Y	1.72***	0.160
	Phsd	-0.40***	0.094
	Pms	0.02	0.07
	IQ	0.73***	0.11
	Yt	1.71***	0.50
	NTC	0.59**	0.21
MS	Y	4.50***	0.88
	Pms	-0.33***	0.08
	Phsd	0.15	0.10
	IQ	0.42**	0.12
	Yt	0.53***	0.16
	NC	0.36**	0.16
LDO	GDP	1.34**	0.56
	Pldo	-0.27*	0.13
	IQ	0.02	0.07
	Yt	0.39*	0.20
	NTC	0.23***	0.07

Table. 2.12: Error correction model for the selected ARDL model

Dependent variable	Regressor	Coefficient	Standard Error
SK	D(Y)	0.10*	0.13
	D(Y(-1))	0.17*	0.04
	D(Psk)	-0.02	0.13
	D(Psk(-1))	0.28*	0.15
	D(PgH)	0.29*	0.15
	D(PgH(-1))	0.33**	0.13
	D(PeH)	0.42**	0.13
	D(IQ)	0.27*	0.13
	D(POP)	0.64	0.45
	CointEq(-1)	-0.57***	0.13
FO	D(GDP)	0.74**	0.16
	D(Pfp)	-0.02**	0.01
	D(Phsd)	0.18	0.12
	D(IQ)	0.34*	0.19
	D(Yi)	0.29***	0.09
	D(IND)	1.06**	0.43
	CointEq(-1)	-0.29**	0.04
HSD	D(HSD(-1))	0.26*	0.13
	D(GDP)	1.37***	0.24
	D(Phsd)	-0.241*	01
	D(Phsd(-1))	0.20**	0.06
	D(Pms)	0.01	0.08
	D(IQ)	0.34*	0.19
	D(NTC)	0.39**	0.16
	D(Yt)	0.66**	0.21
	CointEq(-1)	-0.79***	0.16
MS	D(MS(-1))	-0.26979	0.20
	D(Y)	0.77**	0.22
	D(Y(-1))	2.48***	0.29
	D(Pms)	-0.17**	0.04
	D(Phsd)	0.03	0.01
	D(IQ)	0.04	0.10
	D(NC)	1.07***	0.13
	D(NC(-1))	0.97***	0.09
	D(Yt)	0.39***	0.07
	D(Yt(-1))	0.54**	0.07
	CointEq(-1)	-0.66**	0.11
LDO	D(LDO(-1))	1.09**	0.40
	D(Y)	0.97*	0.23
	D(Y(-1))	0.33**	0.13
	D(Pldo)	-0.24***	0.03
	D(IQ)	0.25	0.53
	D(NTC)	1.29**	0.49
	D(NTC(-1))	0.73***	0.11
	D(Yt)	0.47***	0.16
	D(Yt (-1))	0.38**	0.17
	CointEq(-1)	-0.53***	0.15

The results of institutional quality shows significant results in case of all petroleum products except for LDO in the long run showing a positive impact of institutional quality on petroleum consumption. While the value added by transport sector shows significant impact on petroleum consumption. In case of the remaining fuels the cross price elasticities are not significant neither in the long run nor the short run. These results are in accordance to the previous finding of Siddiqui (2004) on the demand for petroleum products.

Table 2.13: ARDL Diagnostic Tests Result

Dependent Variable	Serial Correlation	Functional Form	Normality	Heteroscedasticity
EC(C)	1.58(0.45)	1.20(0.29)	0.74(0.69)	3.58(0.81)
EC(I)	0.34(0.84)	1.39(0.23)	1.42(0.48)	1.75(0.12)
EC(A)	1.46(0.48)	0.03(0.85)	0.25(0.88)	0.39(0.53)
GC(H)	2.28(0.31)	0.75(0.29)	1.37(0.02)	6.09(0.41)
GC(C)	0.46(0.79)	2.77(0.09)	1.24(0.53)	1.74(0.94)
GC(I)	4.41(0.11)	1.53(0.22)	2.07(0.06)	1.26(0.23)
SK	2.48(0.28)	0.07(0.94)	1.28(0.52)	0.69(0.75)
FO	1.59(0.45)	2.17(0.15)	2.55(0.27)	4.47(0.61)
HSD	2.25(0.18)	0.75(0.10)	1.12(0.57)	7.16(0.78)
MS	0.03(0.85)	0.22(0.66)	0.25(0.88)	1.93(0.75)
LDO	1.12(0.60)	2.15(0.20)	0.02(0.98)	2.60(0.18)

The results of the diagnostic tests are reported in Table 2.13, which shows that the models are well fixed. Moreover the cumulative tests and cumulative sum of squares test were also conducted to identify the model's stability. The results for CUSUM and SUSUMSQ (refer to appendix, Table A4) show that parameters are stable throughout the sample period of 1980-2019.

2.6.2. Inter Factor and Inter Fuel Substitution

The results of Table A2., show that there is high correlation present among the explanatory variables. In such a case applying OLS technique will give biased results. In order to obtain efficient estimates the ridge regression has been utilized and the results are given as under:

2.6.2.1 Ridge Trace plot

The ridge trace plot is a graphical adjunct which plots the estimated standard coefficients (X axis) against the ridge parameters (Y axis). Based on the ridge trace plot given in Figure 2.14, the value of ridge penalty is determined at 0.55. This is the point where all of the parameters are stabilized. The output elasticities and the respective elasticities of substitution are estimated by using the ridge penalty of 0.55.

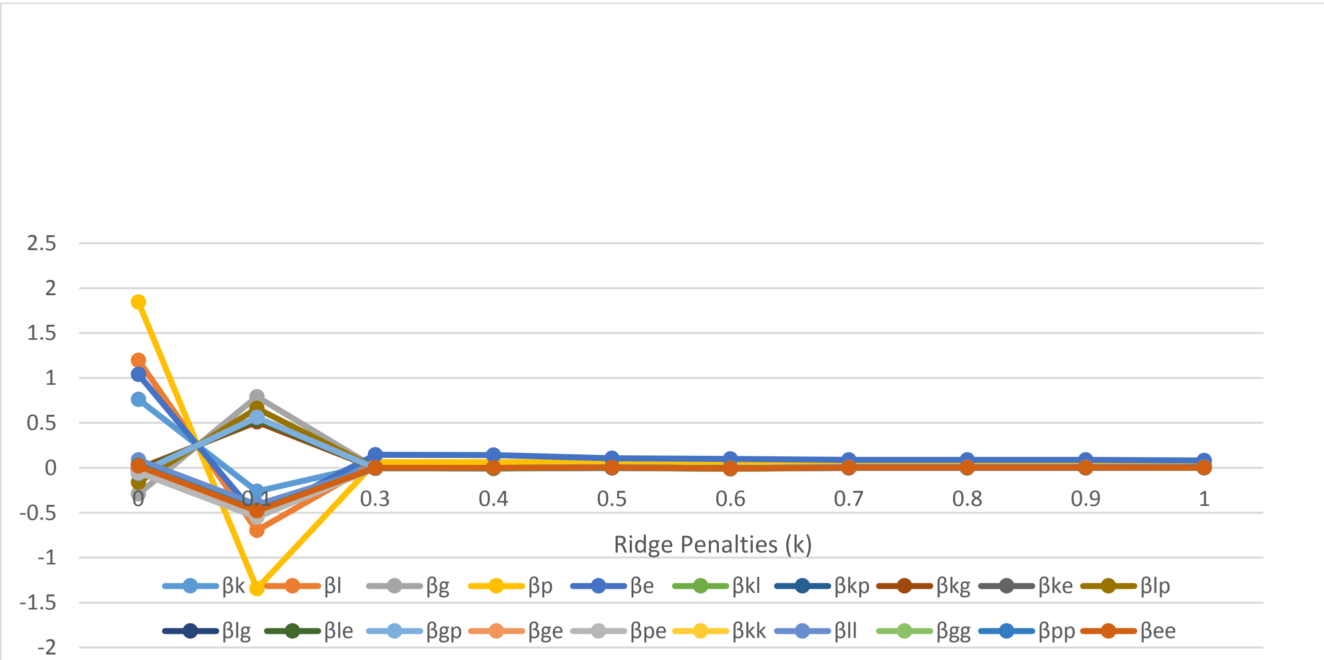

Figure 2.14: Ridge trace plot of the coefficient estimates

2.6.2.2 Ridge Regression Estimates

Table 2.14 shows the results of the ridge regression which are statistically significant. The mode is considered to be reasonable as indicated by all the testing indicators such as the value of F-statistics which shows the significance level of regression equation, the Adjusted R-Square (goodness of fit) and the standard error of estimates.

Table 2.14: Results of the Ridge Regression Model

Ridge Regression with k = 0.55			
Multiple R = 0.958			
R Square = 0.918			
Adjusted R Square = 0.860			
ANOVA table			
	Df	SS	MS
Regression	14	32.016	2.287
Residual	20	2.9840	0.149
F-Value	15.327		
Sig F	0.0		
Variables	Coefficients	Standard errors	P-Value
lnK	0.14	0.01	0.014
lnL	0.14	0.01	0.00
lnG	0.13	0.01	0.00
lnP	0.14	0.01	0.01
lnE	0.15	0.00	0.00
lnK-lnL	0.14	0.01	0.01
lnK-lnP	0.15	0.01	0.00
lnK-lnG	0.14	0.01	0.01
lnK-lnE	0.15	0.00	0.00
lnL-lnP	0.14	0.00	0.00
lnL-lnG	0.13	0.01	0.02
lnL-lnE	0.14	0.00	0.00
lnP-lnG	0.13	0.01	0.00
lnP-lnE	0.14	0.01	0.00
lnG-lnE	0.14	0.01	0.02
lnK-lnk	0.15	0.01	0.01
lnL-lnL	0.14	0.01	0.00
lnP-lnP	0.13	0.01	0.00
lnG-lnG	0.12	0.01	0.02
lnE-lnE	0.14	0.01	0.00

The application of the ridge regression has solved the problem of multicollinearity as shown by the standard errors of all the coefficients which are measured to be less than 0.02. The regression coefficients are also consistent with the economic theory which is indicated by their positive signs. The coefficients of the cross variables and squared variables are also positive. These results indicate increasing returns to scale.

2.6.2.3 Output Elasticities and Elasticities of Substitution

The output elasticities were estimated with the help of equation (2.11) to (2.15). The results shown in Table 2.15 indicate that all factor inputs have positive output elasticities with labor having the highest degree of responsiveness, followed by electricity and natural gas. This shows that over the years the consumption trend of these inputs has been increasing. These results also show that the growth of output of Pakistan is highly reactive to energy consumption and to the labor employed.

Table 2.15: Output Elasticities of factor inputs

Years	φK	φL	φG	φP	φE
1980	0.09	0.37	0.14	0.16	0.17
1981	0.09	0.37	0.14	0.17	0.18
1982	0.09	0.37	0.14	0.17	0.18
1983	0.09	0.37	0.14	0.17	0.18
1984	0.09	0.37	0.14	0.17	0.18
1985	0.09	0.37	0.14	0.17	0.18
1986	0.09	0.38	0.14	0.17	0.18
1987	0.10	0.38	0.14	0.17	0.18
1988	0.10	0.38	0.14	0.17	0.18
1989	0.10	0.38	0.14	0.17	0.18
1990	0.10	0.38	0.14	0.17	0.18
1991	0.10	0.39	0.14	0.17	0.19
1992	0.10	0.39	0.14	0.17	0.19
1993	0.10	0.39	0.14	0.17	0.19
1994	0.10	0.39	0.14	0.17	0.19
1995	0.10	0.39	0.14	0.17	0.19
1996	0.10	0.39	0.14	0.18	0.19
1997	0.10	0.39	0.15	0.18	0.19
1998	0.10	0.40	0.15	0.18	0.19
1999	0.10	0.40	0.15	0.18	0.19
2000	0.10	0.40	0.15	0.18	0.19
2001	0.10	0.40	0.15	0.18	0.19
2002	0.10	0.40	0.15	0.18	0.19
2003	0.10	0.40	0.15	0.18	0.19
2004	0.10	0.40	0.15	0.18	0.19
2005	0.10	0.41	0.15	0.18	0.20
2006	0.10	0.41	0.15	0.18	0.20
2007	0.10	0.41	0.15	0.18	0.20
2008	0.10	0.41	0.15	0.18	0.20
2009	0.10	0.41	0.15	0.18	0.20
2010	0.10	0.42	0.15	0.18	0.20
2011	0.11	0.42	0.15	0.18	0.20
2012	0.11	0.42	0.15	0.18	0.20
2013	0.11	0.42	0.15	0.18	0.20
2014	0.11	0.42	0.15	0.18	0.20
2015	0.11	0.42	0.15	0.18	0.20
2016	0.11	0.42	0.15	0.18	0.20
2017	0.11	0.42	0.15	0.18	0.20
2018	0.11	0.42	0.15	0.18	0.20
2019	0.11	0.42	0.15	0.18	0.20

Utilizing these estimates of output elasticities, the elasticities of substitution were computed using equation (2.22) to (2.31). The results presented in Table 2.16 show that all inputs are substitutes as the elasticities are positive and close to unity. High level of substitution is observed between pairs of capital-petroleum, labor-petroleum and natural gas- petroleum. These results are in accordance with the earlier literature i.e. Medina and Vega Cervera (2001), Smyth et al. (2011), Wesseh et al., (2013) and Lin and Raza, (2020). The substitution elasticity of capital and energy sources suggests that there is possibility of energy conservation with an increased use of energy saving technology in addition to the removal of energy subsidies. According to Tang and Tan, 2013, true energy prices will encourage the use of capital intensive methods in order to save more energy. The substitution possibilities of natural gas- petroleum is highly crucial in case of Pakistan. It will not only reduce the heavy import bill but will also help to reduce the cost of power generation.

Table 2.16: Inter factor and Inter Fuel Substitution Elasticities

Year	σ_{KL}	σ_{KG}	σ_{KP}	σ_{KE}	σ_{LG}	σ_{LP}	σ_{LE}	σ_{GP}	σ_{GE}	σ_{PE}
1980	0.9995	1.002334	1.002335	1.000439	0.998335	0.997125	0.998694	1.004633	0.991123	0.942135
1981	0.999595	1.002329	1.002324	1.000463	0.998349	0.997156	0.998679	1.004602	0.991269	0.944205
1982	0.999605	1.002316	1.002316	1.000487	0.998371	0.99718	0.998663	1.004589	0.991454	0.945852
1983	0.999615	1.0023	1.002307	1.000509	0.998395	0.997204	0.998647	1.004583	0.991652	0.947432
1984	0.999623	1.002284	1.002297	1.000531	0.998417	0.997229	0.998628	1.004574	0.99184	0.94913
1985	0.99963	1.002271	1.002284	1.000552	0.998436	0.997258	0.998609	1.004555	0.992014	0.950971
1986	0.999629	1.002259	1.002274	1.000569	0.998443	0.997269	0.998574	1.004541	0.992161	0.952418
1987	0.999651	1.002237	1.002256	1.00059	0.998487	0.997333	0.998592	1.004515	0.992369	0.954444
1988	0.999652	1.002222	1.002244	1.000605	0.998499	0.997349	0.998566	1.004501	0.992517	0.955768
1989	0.99966	1.002206	1.00223	1.00061	0.99852	0.997382	0.998575	1.004482	0.992619	0.95671
1990	0.999668	1.002192	1.002213	1.000618	0.99854	0.99742	0.998577	1.004455	0.99273	0.958008
1991	0.999674	1.002172	1.002197	1.000624	0.998563	0.997456	0.99858	1.004437	0.992855	0.959197
1992	0.999652	1.002158	1.002189	1.000625	0.998545	0.997426	0.99852	1.004433	0.99293	0.959614
1993	0.999656	1.002138	1.002174	1.000621	0.998564	0.997453	0.998534	1.004418	0.993007	0.960138
1994	0.999658	1.002117	1.00216	1.000615	0.998583	0.997476	0.998546	1.004408	0.993082	0.960601
1995	0.999651	1.002097	1.002147	1.000613	0.998591	0.997482	0.998533	1.004402	0.993167	0.961088
1996	0.999652	1.002077	1.002132	1.000607	0.998608	0.997507	0.998545	1.004388	0.993232	0.961626
1997	0.999667	1.002053	1.002113	1.000599	0.998647	0.997563	0.998593	1.004373	0.993314	0.962323
1998	0.999678	1.002034	1.002098	1.000588	0.998676	0.997606	0.998639	1.00436	0.99335	0.962645
1999	0.99968	1.002024	1.002086	1.00058	0.998685	0.997628	0.998658	1.004339	0.993356	0.962913
2000	0.999667	1.00201	1.00207	1.000575	0.998677	0.99763	0.99863	1.004314	0.9934	0.963597
2001	0.999666	1.001993	1.002049	1.000572	0.998689	0.997664	0.998633	1.004285	0.99346	0.964565
2002	0.999672	1.001977	1.002029	1.000567	0.998709	0.997709	0.998655	1.004256	0.993515	0.965483
2003	0.999672	1.001969	1.002005	1.000569	0.998714	0.997754	0.998651	1.004205	0.993558	0.966853
2004	0.99968	1.001957	1.001979	1.000571	0.998731	0.997811	0.998665	1.004153	0.993623	0.968166
2005	0.999679	1.001935	1.001958	1.000571	0.998746	0.997839	0.998661	1.004128	0.99372	0.969002
2006	0.9997	1.001897	1.001931	1.000568	0.998802	0.997915	0.998716	1.00411	0.993876	0.969978
2007	0.9997	1.00187	1.001916	1.000558	0.998823	0.997935	0.998732	1.004106	0.993952	0.970214

2008	0.999701	1.001847	1.0019	1.000538	0.998842	0.997961	0.998767	1.004098	0.993964	0.970253
2009	0.999706	1.001821	1.001882	1.000523	0.99887	0.997998	0.998805	1.004091	0.994013	0.970512
2010	0.999704	1.001797	1.001867	1.000518	0.998885	0.998015	0.998806	1.004088	0.99409	0.970942
2011	0.9997	1.001779	1.001853	1.000509	0.998894	0.998031	0.998811	1.00408	0.994124	0.971244
2012	0.9997	1.00176	1.001839	1.000495	0.998909	0.998052	0.998833	1.004072	0.994145	0.971385
2013	0.999696	1.001735	1.001828	1.00049	0.998923	0.998062	0.998833	1.004077	0.994223	0.971645
2014	0.999686	1.001709	1.00182	1.000461	0.998934	0.998063	0.998858	1.004106	0.994202	0.971257
2015	0.999683	1.001721	1.001803	1.00042	0.99892	0.998088	0.998918	1.004052	0.993982	0.970842
2016	0.999683	1.001957	1.001979	1.000571	0.998731	0.997811	0.998665	1.004153	0.993623	0.968166
2017	0.999685	1.001935	1.001958	1.000571	0.998746	0.997839	0.998661	1.004128	0.99372	0.969002
2018	0.9997	1.001897	1.001931	1.000568	0.998802	0.997915	0.998716	1.00411	0.993876	0.969978
2019	0.9997	1.00187	1.001916	1.000558	0.998823	0.997935	0.998732	1.004106	0.993952	0.970214

These results also imply that Pakistan can shift its load of power generation from costly oil to natural gas as there is positive elasticity of substitution between them. However, due to the exhausting natural gas reserves, there is much need of price reforms of the energy items. The low prices of natural gas are constraining its supply (SBP, 2015). Removal of subsidies will result in competitive gas prices which will discourage inefficient gas consumption and increase gas reserves by encouraging fresh exploration. The substitution elasticity of labor and energy sources exhibits a positive trend over time. According to Mukherjee (2008), in order to substitute labor for energy the labor force has to be equipped with education and skills. This in turn will raise the labor productivity that will result in energy conservation by appropriate use of energy saving techniques (Mandal and Madheswaran (2011), Lin and Ouyang (2014)).

2.7 Conclusion and Policy Implications

The first objective of this chapter is to analyze the factors affecting energy demand by the household, commercial, industrial and agricultural sectors. Energy includes electricity, natural gas and petroleum products. The demand function for each sector has been computed using the bound testing approach to cointegration (ARDL approach) developed by Pesaran et al. (2001). The results suggests that the number of users and income have a positive effect on energy (gas, electricity and petroleum products) consumption in all the sectors (household, industrial, commercial and agricultural) while, the own price exerts negative impact on the energy demand with expected signs. The short run elasticities are much lower than the long run estimates which suggests that the demand management policies will have a stronger effect over time. The magnitude of the price elasticities is quite small. Moreover, the short run income elasticities are found to be insignificant in most of the cases. These results of insignificant short run income elasticities imply that consumers do not buy energy appliances which increase the consumption of energy in the short run. Such purchases are usually made in the long run. These results are also supported by Iqbal and Nawaz (2020), whose results show that cash transfer do increase the purchasing of energy appliances. The results for institutional quality index, measured by using the average of government stability, government accountability, investment profile, law and order and bureaucratic quality, show significant impact on energy consumption. These results suggest that increasing the prices of energy alone may not be affective for energy conservation purposes. The government must also provide alternative energy saving appliances along with a focus upon the population growth rate in the country. It should formulate such policies that could reduce the population growth rate. Moreover, the results also indicate that the energy sector reforms should also pay attention towards institutional constraints in addition to capacity building efforts. Although, village electrification and natural gas provision programs which require large scale infrastructure have been carried out by the state, there is now a need to focus on decentralized development plans. As already discussed in the introduction, the power generation capacity of Pakistan was increased by 13,298MW during the phase of 2016-21 (NEPRA, 2020). However, in order to utilize this increased capacity there is a need of efficient T& D network to transmit electricity to the load centers. There are a number of constraints in the existing T & D network of NTDC which cause underutilization of the efficient plants. In such a situation small scale decentralized generation and distribution efforts will require a lower cost as compared to the expansion of the grid at national level. These results are beneficial not only for policymakers but also private investors as they provide important insights regarding the market for energy consumption.

The second objective of the chapter is to examine the possibility of inter factor and inter fuel substitution between the labor, capital and energy sources (electricity, natural gas and petroleum products). The ridge regression methodology has been applied due to the problem of multicollinearity present in the data. The positive output elasticities indicates that all the factors contribute towards economic growth. These results also indicate that the consumption of these factor inputs have increased over the time leading to a higher economic growth. Moreover, positive substitution enhances the need of increased investment in efficient energy saving technologies. The results also suggests substitution between labor and energy items which means improved skills and knowhow could result in energy conservation. Substituting gas for oil will be very favorable in Pakistan as it will address the issue of heavy import bill. However, on view of the depleting gas reserves substitution of gas should be brought with the increase in prices of natural gas. Natural gas is highly subsidized in Pakistan which leads to it inefficient usage. In order to discourage its inefficient use and encourage its exploration more competitive prices should be charged. These results are critically significant for energy conserving and especially for increasing power generation capacities.

Chapter 3

Inter temporal Analysis of Household Energy Demand in Pakistan: Evidence from Micro Data

3.1 Introduction

Energy consumption plays an imperative role in the welfare of households (HHs) both for the developed as well as the developing countries. Its significance can be traced through the share of expenditure HHs spend on energy usage (Irfan, Cameron and Hassan, 2018). The expenditure share of HHs on energy consumption varies with prices, household income, household size and other household characteristics. Along with the increasing population, the energy demand of the domestic sector of Pakistan is rapidly increasing. Since 1990's, the consumption patterns of commercial energy reveals that the share of household sector in the commercial energy use is rising, with a high growth rate (Rahman, 2021). However, the prices of energy products used by the HHs have also been increasing during the same period due to the reduction in subsidies and fluctuation in the international oil prices. The international oil prices have been increasing since 1990's. The oil price which was $10/barrel in 1995 escalated to $110/barrel in May 2014 leading to a rise in oil price domestically from Rs.9 per liter (1995) to Rs.107 per liter in May 2014. In order to protect consumers, the petroleum products prices have been capped several times (Afia, 2008). The rising oil prices led to the substitution of petrol/diesel for CNG which raised the demand for natural gas.

The international prices of oil exhibited significant volatility in 2014 and declined to the same level as in 2010 due to persistent increase in US crude stocks and higher supplies from OPEC producers (Middle East). During the end of 2014, following the international trend the decline in oil prices within Pakistan resulted in oil crisis (SBP, 2018). As a result there were long ques on the petrol pumps for a few days followed by the emergency response by the government. Moreover, the electricity generation cost is also influenced by the international oil prices as 65 percent of the total electricity is generated by thermal sources using imported furnace oil.

Pakistan stays vulnerable to any fluctuations in the international oil prices as there is very little effort made to study and analyze the impact of such shocks (Rehman et al., 2020). In addition to the fluctuating oil prices the government of Pakistan has also been reducing subsidies on commercial fuels due to the mounting fiscal burden. However, electricity and natural gas which comprise a major share of household energy expenditure are still highly subsidized for the domestic sector (Khalid and Salman 2020). The estimates of price elasticities in the previous chapter suggest that the domestic sector is not much responsive to the changes in energy prices. These results highlights the need to investigate whether targeting subsidies on energy fuels for the domestic sector will be a suitable policy measure in order to cut down the inefficient usage? Such a policy measure needs to be designed very carefully as raising price for energy products will be unfavorable for the poor. Hence, in addition to demand elasticities, the consumption expenditures by different income quintiles on energy sources also needs to be considered in order to analyze how households of different social classes will be affected by higher prices of energy products. This chapter seeks to conduct a detailed analysis of the patterns of household expenditure on three main energy sources i.e. electricity, natural gas and petrol and diesel using Pakistan Social and Living Standards Measurement Survey (PSLM) data for the years 2005-06, 2010-11 and 2015-16 for urban and rural HHs separately. The analysis of the consumption expenditure on energy fuels by different income quintiles will not only provide information on the fuel switching behavior of the poor households but it will also demonstrate how successful the government has been in providing affordable energy to the lower classes through village electrification programs. Furthermore, the price and income elasticities have been computed with the Extended Linear Expenditure System methodology which was also used by Burney and Akhtar (1990). Estimating price and income elasticities over three different periods of high (2005-06), low (2010-11) followed by fluctuating oil price (2015-16) will provide useful information regarding the effect of international oil prices on our energy prices and energy consumption. There are no recent estimates of demand elasticities at the household level of Pakistan for various energy sources. Previous studies on energy demand by the household sector have not analyzed the demand for petrol and diesel along with the other fuels consumed by the HHs. In order to analyze the impact of changing energy prices in response to the international oil price shocks it is necessary to consider the consumption of petrol and diesel by HHs as the petroleum products are directly influenced by such changes.

3.1.1 Objectives of the Study

The broad objectives of this chapter are as follows:

- To examine in detail the intertemporal patterns of household expenditure on three main energy sources i.e. electricity, natural gas and petrol and diesel for rural and urban households.
- To calculate price and income elasticities for rural and urban households.

3.1.2 Contribution of the Study

The analysis of the consumption expenditure on energy fuels by different income quintiles will not only provide information on the fuel switching behavior of the poor households but it will also demonstrate how successful the government has been in providing affordable energy to the lower classes through village electrification programs. Furthermore, the price and income elasticities have been computed with the Extended Linear Expenditure System methodology which was also used by Burney and Akhtar (1990). Estimating price and income elasticities over three different periods of high (2005-06), low (2010-11) followed by fluctuating oil price (2015-16) will provide useful information regarding the effect of international oil prices on our energy prices and energy consumption. There are no recent estimates of demand elasticities at the household level of Pakistan for various energy sources. Previous studies on energy demand by the household sector have not analyzed the demand for petrol and diesel along with the other fuels consumed by the HHs. In order to analyze the impact of changing energy prices in response to the international oil price shocks it is necessary to consider the consumption of petrol and diesel by HHs as the petroleum products are directly influenced by such changes.

3.1.4 Organization of the Study

The remaining chapter is structured as follows. Section 3.2 discusses the trends in household's energy consumption, Section 3.3 gives the literature review, Section 3.4 analyzes the theoretical framework, Section 3.5 explains data and methodology, Section 3.6 analysis the intertemporal patterns of household consumption expenditures, 3.7 delves into the results while Section 3.8 concludes the chapter.

3.2 Trends in Household Energy Consumption

Trends in the energy consumption by the household sector during the period 1990-2018, as presented in Table 3.1 and Figure 3.1, shows that household sector consumed 3.5 MTOE (20.7 percent) of energy in 1990-91 from the total energy consumption of around 11.6 MTOE, which increased to 10 MTOE (23.2 percent) in 2017-18. During this period the HHs' use of commercial energy (5%) has grown at a faster pace than the per annum growth in total energy consumption (4.1%) resulting in rising share of household sector in commercial energy consumption as indicated in the previous chapter.

Table 3.1: Household's Commercial Energy Consumption

Year	HH Energy Consumption (MTOE)	HH Energy Consumption (% of Total Energy Consumption)
1990-91	3.5	20.66
1995-96	4.7	20.51
2000-01	5.8	23.07
2005-06	7.1	20.78
2010-11	8.7	22.46
2015-16	10.5	23.17
2017-18	11.7	23.20

Source: Pakistan Economic Survey (various issues)

However, the analysis of household energy use by source has shown a large inter-fuel substitution during the period, with the share of oil declining consistently from a significant 7 percent of total household energy use in 1990-91 to a negligible 1 percent by 2017-18 (see, Fig 3.2).

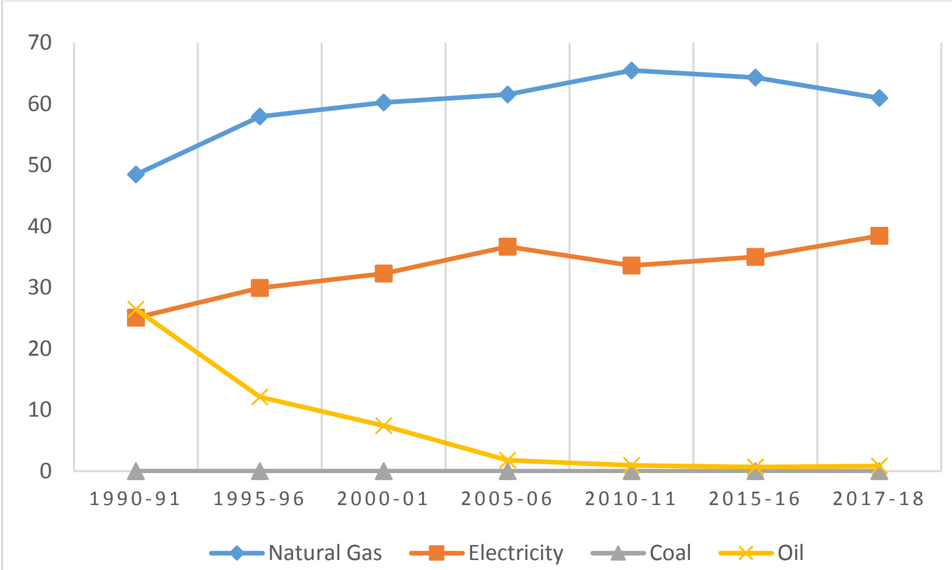

Figure 3.1: Share of Energy in Household Energy Consumption (%)

Source: Pakistan Economic Survey (various issues)

This decline has been matched by a sharp increase in the share of electricity (13.33 percentage points) and natural gas (12.6 percentage points).

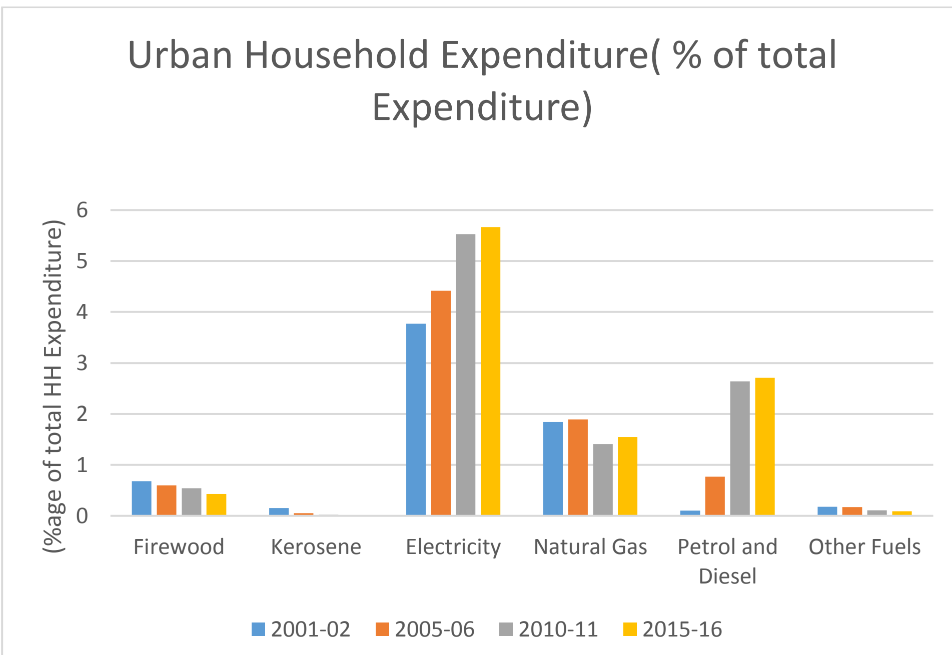

Figure 3.2: Urban Household Expenditure on Energy Sources

Source: Authors Calculation using PSLM survey (2001-02, 2005-06, 2010-11, 2015-16)

Currently, natural gas is the predominant commercial energy source being used by the household sector which accounts for around 61 percent of total household energy use in 2017-18. The share of coal in household energy use has been almost nil during the same period. On the other hand, if we analyze the expenditure of HHs on energy sources reported in the Pakistan Social and Living Standard Measurement Survey, it can be seen that the expenditure on electricity is the highest for both urban and rural household followed by gas.

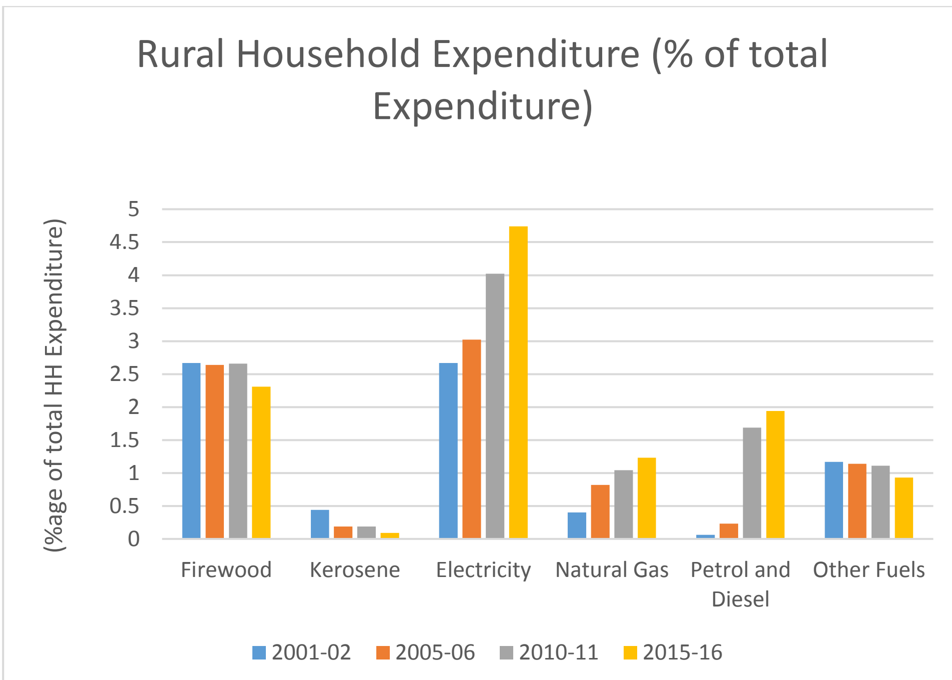

Figure 3.3: Rural Household Expenditure on Energy Sources

Source: Authors Calculation using PSLM survey (2001-02, 2005-06, 2010-11, 2015-16)

It is also observed that the expenditure on petrol and diesel has increased by a significant amount since 2010 (shown in Figure 3.2 and 3.3). This rise can be attributed to the reduced oil prices which has raised the demand for petroleum products. While the expenditure on Firewood, Kerosene oil and other fuels which includes household expenses on coal and other biomass fuels such as dung cakes and crop residue, which are important sources of energy, especially for the rural household.

3.3 Literature Review

The literature on household energy demand is limited in case of developing countries like Pakistan (Ngui et al. 2011). Several studies for example Filippini and Pachauri (2004), Atakhanova and Howie (2007), Athukorala and Wilson (2010), Shi et al. (2012) and Lin, Rizov and Wong (2014) have focused on the demand for just one energy source i.e. electricity. Other studies have focused on a group of fuels used by HHs as firewood, charcoal, electricity, natural gas etc. Shittu et al., (2004) computed income elasticities of fuels for poor, average, and wealthy HHs of Nigeria. By applying logit model they found that among different fuels, only firewood had negative income elasticity in case of poor, average and wealthy HHs with values of -5.02, -4.94, and -4.31 respectively. Later in 2008, Gundimeda and Köhlin estimated expenditure and price elasticities for various income groups in urban and rural areas of India using LA-AIDS model. They found that estimates of price elasticity for fuelwood, electricity, LPG and kerosene oil were same in case of urban and rural HHs. While for Fuelwood and LPG the price elasticities were close to one.

Maria, Bond and Willson (2012) investigated the income and elasticities of energy consumption in Mozambique. Their results suggested that fuelwood (-0.41) and charcoal (-0.28) were more price inelastic in comparison to candles (-0.88) and electricity (-0.60). The income elasticity of kerosene, candles and electricity was greater as compared to that of charcoal and firewood. In the same way Akpalu, Aglobitse and Dasmani (2011) found charcoal, firewood and LPG to be price inelastic as compared to kerosene among different fuels.

Ngui et al., (2011) computed the price and expenditure elasticities for urban and rural HHs in Kenya. They found that electricity was more price elastic with a value of -0.88 as compared to fuelwood, kerosene oil, charcoal and LPG. Kerosene oil had the highest expenditure elasticity with a numerical value of 1.06. Other studies have also focused on fuels used in vehicles such as petrol and diesel (Ajanovic et al., 2012; Akinboade et al., 2008; Baranzini and Weber, 2013; Dahl, Ajanovic and Schipper 2012; Lin and Zeng, 2013 and Winebrake et al., 2015). These studies have used country level data and estimated price and income elasticities for gasoline (petrol) and diesel. The price elasticities were found to be very low ranging from -0.3 to -0.85. However the income elasticities varied widely ranging from 0.3 to 1.4.

In case of Pakistan there are very few studies that have estimated price and income elasticities for energy demand using household micro data. Iqbal (1983) computed the price and income elasticities for 4 energy sources i.e. electricity, natural gas, LPG, coal and kerosene oil using annual data for the time period 1960-1981. He formed two fuel groups by adding electricity, natural gas and LPG in the first group and coal and kerosene oil in the other group. The results suggested that both of the energy groups were very less responsive to income and price changes.

Later Burney and Akhtar (1990), estimated price, income and expenditure elasticities for fuel demand using the Household Income and Expenditure Survey 1984-85. The urban and rural HHs were analyzed separately with the help of extended linear expenditure system for the five fuel categories. The own price elasticities were found to be very low whereas firewood had positive price elasticity. The expenditure elasticities were positive for all the fuel types except for firewood. The study reported that the price elasticities for electricity, natural gas, coal and oil are very low. According to Burney and Akhtar, these low price elasticities showed that only the minimum fuel requirement of the HHs is being met.

Later in 2015, Khan et al. estimated income and price elasticities using Extended Linear Expenditure System for different fuels. Their results suggest electricity followed by natural gas have been the dominant fuels used by urban HHs while firewood and electricity were the main fuels used by rural HHs in both periods i.e. 2001-02 and 2010-11. However, all fuel types had low income and price elasticities indicating that energy consumption is less likely to change with income and price changes for urban as well as rural HHs. The study also found that the proportion spent by urban HHs on fuels was less as compared to the rural HHs. Irfan, Michael, Cameron and Hassan (2017) used the Linear Approximate Almost Ideal Demand System (LA-AIDS) model to investigate the expenditure and price elasticities at urban, rural, and national levels by pooling three data sets (2007-08, 2010-11 and 2013-14) of PSLM surveys. They found that all fuels excluding natural gas had very low price elasticities at the country level and for the urban HHs. In case of rural HHs, LPG and natural gas had higher estimates of price elasticity than the urban HHs. The expenditure elasticities were all positive ranging between zero and one.

Omer, M. (2018), investigated the price and income elasticities for petrol, CNG and diesel using monthly data over the period of 2004-2015 for the transport sector. Their estimates of price elasticities show very small numerical values of own price and cross price elasticities in the short run. However, in the long run, the demand elasticities are comparatively higher.

The literature on household energy demand suggests that the estimates of price and income elasticities play a significant role in energy price reforms. Analyzing the responsiveness of

HHs towards income and energy prices provides significant information for policy makers in designing energy subsidies and taxes. This chapter adds to the literature by analyzing in detail the demand for petrol and diesel along with the other fuels consumed by the rural and urban HHs for different income quintiles.

3.4 Theoretical Framework

This study estimates income and price elasticities for the three energy items i.e. electricity, gas and petrol using an Extended Linear Expenditure System (ELES) formulated by Lluch (1973). In comparison to the Linear Expenditure System (LES), this system provides better estimates of price elasticity and also measures the impact of relative prices on savings of the households by incorporating the total consumption expenditures. There are other demand systems which are better than the ELES in terms of flexibility such as the Almost Ideal Demand System (AIDS) given by Deaton and Muellbauer (1980a). Due to the unavailability of prices for the fuels consumed by households in the PSLM data set, the application of AIDS is not possible.

The ELES is based on the standard utility maximization behavior of the household[5]. The household expenditure decision is assumed to be made on per capita basis and is independent of other socio-economic factors as gender, age, education etc. it is expressed as

$$e_i = p_i x_i = p_i \gamma_i + \beta_i (y - \sum p_j \gamma_j) \tag{3.1}$$

[5] The ELES can be derived from maximizing utility function (Stone Geary type) where the preferences are directly additive $U(x) = f_i x_i = \beta_i \log(x_i - r_i)$.With $x_i > -r_i, \beta_i > 0 \ and \ \sum \beta_i = \mu$.

where, i = 1, 2, …, n goods, e_i is the per capita expenditure of household on good i, p_i is the price of good i, x_i is per capita consumption of household on good i, y is per capita income of household, while γ_i $\beta_i$are the parameters which will be estimated. The βi's show the marginal propensity to consume of good i with ∑ βi = μ is the overall marginal propensity to consume. While the parameter γ_i represents the basic needs or subsistence quantity of good i, while $\sum p_j\gamma_j$ indicates total subsistence expenditure. The expression $(y - \sum p_j\gamma_j)$ denotes supernumerary income. The relationship shown by Equation (4.1) is referred to as the ELES[6].

The aggregate expenditure system is obtained by adding up the expenditure equations for all the goods as

$$E = (1 - \mu)\sum p_i\gamma_i + \mu y \tag{3.2}$$

The system of equations given by equation 3.1 need to be estimated simultaneously as $\gamma_i$is present in all the equations. This generally requires maximum likelihood function as it imposes cross equation restriction. However, the term $p_i\gamma_i$is independent of the unit of observations since the commodity prices are identical for each household in cross section data. Hence, it can be replaced with γ_i^*. The stochastic specification of the ELES is given as

$$e_{ih} = \alpha_i + \beta_i y_h + \epsilon_{ih} \tag{3.3}$$

where, h = 1, 2, …, H HHs, $\alpha_i = \gamma_i^* - \beta_i\sum\gamma_i^*$and ϵ_{ih} is the error term.

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[6] A LES differs from an ELES in the sense that instead of y, total household expenditure (E) appears in the equation. Thus, instead of supernumerary income, there is an expression $(E - \sum p_j\gamma_j)$ referred to as supernumerary expenditure. The coefficient of $(E - \sum p_j\gamma_j)$ denoted say as βi* is interpreted as marginal budget shares, i.e., marginal propensity to consume out of total expenditure, such that ∑βi* =1. The βi* can be obtained from βi as βi*= βi/μ.

The ELES has a disadvantage over the other demand systems as it assumes that the marginal utility of a product is not influenced by the consumption of any other product. This assumption of additive preferences assumption as it is not very credible in case of consumption items (Alderrman, 1988). The ELES has the benefit of providing estimation of price and income in absence of data for prices. As the data for prices of energy goods under examination is not available we make use of the ELES system. A few studies have made use of LA-AIDS model to estimate to compute demand elasticities for energy goods of Pakistani households. Considering the variability in energy prices within years and spatial differences causes a serious impediment in the usage of these model. As it assumes fixed prices for energy sources across cross sections and throughout the year. Such assumptions cannot be made while estimating demand elasticities for petroleum products, as their prices fluctuate greatly within a year[7].

3.5 Data and Methodology

This section is divided into two subsections. First section contains the details related to data used in this chapter. The empirical methodology is described in the second subsection.

3.5.1 Data

This study is based on the micro level data of the Pakistan Social and Living Standards Measurement (PSLM) Survey 2005-06, 2010-11 and 2015-16, compiled by the Pakistan Bureau of Statistics. The PSLM 2005-06 data are based on a nationally representative sample of 15417 HHs, with 5997 HHs (39%) living in urban areas and 8818 (57%) residing in rural areas. For 2010-11 the data are also based on a nationally representative sample of 16,313 HHs, with 6,572 HHs (40%) living in urban areas and 9,741 (59.7%) residing in

[7] Discussed in detail in chapter 2.

rural areas. While for 2015-16 the data are also based on a nationally representative sample of 24239 HHs, with 16,155 HHs (66%) living in urban areas and 8,083 (34%) residing in rural areas[8]. The household income and expenditure module of all the three survey rounds is compatible with each other as they report expenditures on the same range of commodities and can thus be used for inter-temporal comparison. Moreover, in order to control for the effect of inflation the real monthly household income and expenditures have been calculated[9] by keeping 2005 as base year.

3.5.2 Empirical Methodology

The system of equations as described by equation (3.3), is one of identical regressors in which every left-hand side variable is regressed upon the same set of exogenous variables. Estimation of each of its equations separately for different commodities, by the Ordinary Least Squares (OLS) method, is equivalent to the system's maximum likelihood estimation (Burney and Akhtar, 1990; Khan et al., 2015). OLS regression is widely used for linear statistical models which is given as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k k + \varepsilon \qquad (3.4)$$

Where Y is the dependent variable, $\beta_0$is he intercept of the model, $X_i$is the ith explanatory variable and ε is the random error with expectation 0 and variance σ^2. The OLS estimates of $\alpha_i$and β_i can be used to estimate the maximum likelihood estimates of μ, $\gamma_i^*$and $\sum \gamma_i^*$ with the help of the following relationship

(1) $\mu = \sum \beta_i$

[8] The sample from all the survey rounds excludes households for which the reported total consumption expenditure was zero or missing.

[9] Using CPI indices

(2) $\sum \gamma_i^* = \sum \frac{\alpha_i}{1-\mu}$

(3) $\gamma_i^* = \alpha_i + \beta_i \sum \gamma_i^*$

The demand elasticities are computed as

(i) Income Elasticity of Good i: $\eta_{iy} = \beta_i (\frac{y}{e_i})$

(ii) Own-price Elasticity of Good i: $\eta_{ii} = (1 - \beta_i) \left(\frac{\gamma_i^*}{e_i}\right) - 1$

(iii) Cross-price Elasticity of Good i: $\eta_{ij} = -\beta_i (\frac{\gamma_j^*}{e_i})$

From (iii) it can be seen that for a positive cross price elasticity either $\beta_i$has to be negative (good i be inferior) or γ_j^*has to be negative (good j be a luxury good). Otherwise the uncompensated cross price elasticities under the ELES can take up only negative values. Hence, these negative elasticities are inconclusive under normal circumstances. However, OLS has some limitations with heteroscedasticity as the main concern for cross sectional data (Hayes and Cai, 2007). In order to check for the reliability of the results, several diagnostic tests are used each model.

3.6 Inter temporal Analysis of Household Energy Expenditures

Table 3.2 shows the average monthly expenditures of the three energy goods under discussion of HHs using constant prices of 2001-02. The annual increase in real expenditures on the three energy sources is approximately 16 percent for the urban HHs for the period 2006-11 while for the rural HHs it is 6.2 percent. Whereas during the period 2011-16 it is 5.2 percent for the urban HHs and 10.4 percent for the rural HHs. It can be seen that the real expenditure of rural HHs have increased at a faster pace. The increase of household budget share on energy sources (mainly electricity and natural gas) may be due to both rise in energy prices and greater utilization of energy on household appliances due to higher levels of income over the years. The higher utilization of household appliances over time is supported by Khan and Khalid (2010) who found that both urban and rural HHs increased the expenditure share on durable goods (the increase being higher for rural HHs (2.5 times)) with the passage of time[10].

Table 3.2: Average household expenditure on fuels

Average household Expenditure (Rs. Per month)						
	2005-06		**2010-11**		**2015-16**	
	Urban	Rural	Urban	Rural	Urban	Rural
Electricity	256.45	143.03	465.85	216.89	565.57	253.58
Natural Gas	168.27	87.79	146.18	128.91	156.73	186.70
Petrol and Diesel	169.72	101.14	320.20	134.52	411.68	157.17
Total	523.8194	298.54	932.80	391.55	1176.98	597.45
Other	16072.58	14917.33	19003.91	17207.27	96145.37	62101.46

Table 3.3 shows that within the three energy sources, both urban and rural HHs had highest expenditure shares on electricity followed by petrol during the three years under review. The expenditure share of natural gas of the urban sector reduced during 2002-11,

[10] The durable goods category includes expenditures on household appliances, such as refrigerators, freezers, electric fans, air coolers, air conditioners, etc.

which may be driven by the fall in average household size[11]. Due to the fall in average household size the usage of natural gas for cooking and heating purposes declines. Another reason might be the increase in efficiency of appliances using natural gas overtime. On the other hand the rural HHs have increased the usage of natural gas over the phase of 2006-2016 due to its easy availability and the fuel switching behavior form firewood to natural gas of rural HHs. The fuels switching behavior of the rural HHs is also supported by Khan, et al. (2015) who found that over the years with the increase in gas connections in the rural areas the use of firewood has declined along with the increased use of natural gas. Comparison of these results with the earlier estimates by Burney and Akhtar (1990) and Khan, et al. (2015) shows that increase in the average expenditure share on energy sources is mainly driven by higher budgetary outlays on electricity caused by the greater use of household appliances by both urban and rural HHs across the country.

Table 3.3: Average household expenditure on energy sources

Average household expenditure (% of total household expenditure)						
	2005-06		**2010-11**		**2015-16**	
	Urban	Rural	Urban	Rural	Urban	Rural
Electricity	3.77	2.02	5.53	4.02	5.67	4.74
Natural Gas	1.89	0.82	1.41	1.04	1.55	1.23
Petrol and Diesel	0.10	0.06	2.64	1.69	2.71	1.94
Total	7.06	3.89	9.58	6.26	9.93	7.91
Others	92.91	96.09	90.42	93.73	90.07	92.09

[11] The average household size fell from 6.9 in 2005-06 to 6.2 in 2010-11.

The average real household expenditure in per capita given in Table 3.4 shows that per capita expenditure of electricity on case of urban HHS increased at a higher rate than the rural areas during the period 2006-16. For the period 2006-2011 it raised by 16% for the urban areas while 8.5% for rural areas. Whereas for the period 2011-16 it raised by 5.6% for urban HHs and 4% for rural HHs. On the other hand in case of natural gas the rise for urban HHs in the period 2005-11 was by 10% and that of rural HHs was 11.6%. During the phase 2010-16 the increase of per capita expenditure in case of urban HHs for gas was 3.5% and that of rural HHs was 4%. In case of petrol the rise in expenditure was 18% for the urban HHs in the period 2006-11 and 3.6% for rural areas. During the phase 2010-16 the increase of per capita expenditure in case of urban HHs for petrol was 1.5% and that of rural HHs was 3.5%. This shows that the rise in per capita expenditures on energy sources is higher in the period of 2005-10 than that of 2011-16.

Table 3.4: Average household expenditure on fuels

Average household expenditure per capita (Rs. Per month)						
	2005-06		**2010-11**		**2015-16**	
	Urban	Rural	Urban	Rural	Urban	Rural
Electricity	46.26	24.70	83.31	36.60	106.69	44.04
Natural Gas	17.37	12.51	26.05	19.83	30.56	23.7
Petrol and Diesel	30.82	17.66	58.71	20.70	63.33	24.41
Total	94.45	55	168.07	77.13	201	92.15
Others	4448.57	3842.36	5149.479	3976.99	21287	12094.55

The average real monthly household income and expenditure (total and energy) in per capita terms for urban and rural HHs dividing the HHs in quintiles is given in Table 3.5. The household per capita income is higher than the per capita expenditure across all expenditure quintiles in all the three periods 2005-06, 2010-11 and 2015-16. The highest growth in real household per capita monthly income during the period of 2006-2016 is seen in the fourth quintile, followed by the by the fifth and third quintiles, with growth being lowest for HHs in first quintile in case of urban HHs. Whereas for the rural HHs, the highest growth in real per capita is observed in the fifth quintile followed by the fourth and fifth quintile, with growth being lowest for HHs in the first quintile. This finding are similar to that of Khan, et al. (2015) which suggest that the income inequality between the richest and the poorest segments of the society are worsening over time. The per capita real expenditure on energy sources i.e., electricity, natural gas and petrol is seen to rise with income across all quintiles for urban and rural HHs while being highest for HHs in the fifth quintile.

Growth in real per capita expenditure on fuels is seen to be higher for rural HHs across all quintiles in comparison to urban HHs. This growth is most likely to be driven by the higher demand of household appliances and vehicles in response to the rising income levels of rural HHs. According to Khan and Khalid (2010), this rise in income is due to the rising farm support prices in addition to the increasing flows of domestic and foreign remittances.

Table 3.5: Average per Capita Real Household Expenditure and Income by Expenditure Quintiles

Expenditure quintiles	**Average per capita total household monthly expenditure (Rs.)**		**Average per capita total household monthly income(Rs.)**		**Average per capita total household monthly expenditure on fuel (Rs.)**	
2005-06	Urban	Rural	Urban	Rural	Urban	Rural
First	418.32	167.38	511.29	270.67	28.12	26.31
Second	551.52	347.77	600.58	478.92	54.16	52.58
Third	779.44	529.69	839.30	699.91	87.27	86.31
Fourth	1137.22	816.64	1396.55	1048.41	158.57	142.41
Fifth	2084.28	1087	2179.59	1669.81	363.53	340.23
2010-11						
First	594.05	143.56	601.6072	455.4932	27.05	28.53
Second	852.21	620.25	859.43	691.8005	59.74	56.09
Third	1096.01	771.05	1546.29	869.4424	97.56	89.82
Fourth	1478.20	879.99	1807.03	1358.8211	168.53	195.32
Fifth	3216.43	939.39	3965.76	2127.677	485.92	486.78
2015-16						
First	627.91	187.43	647.59	514.60	32.24	39.61
Second	1067.41	689.03	1169.45	823.34	76.31	72.45
Third	1505.16	866.76	1609.13	1029.95	122.07	115.76
Fourth	2710.66	1125.43	2909.1	1609.1	191.49	193.07
Fifth	4062.21	2013.41	4265.32	2467.86	501.24	492.34
Average annual growth rate (%)						
First	5.01	1.197	2.66	9.01	1.46	5.05
Second	9.35	9.81	9.47	7.19	3.78	3.77
Third	9.31	6.36	9.17	4.71	3.88	3.41
Fourth	13.83	8.67	10.83	5.34	2.07	3.55
Fifth	9.48	8.52	9.56	4.77	3.98	4.47

The real per capita expenditure on individual energy sources by quintiles is given in Table 3.6. It can be seen that the per capita expenditure on electricity, natural gas and petrol has by and large, increased for each quintile for both urban and rural HHs. In terms of annual growth during the period, it can be seen that the growth in real per capita expenditure on these energy sources is higher for rural HHs in most of the quintiles. The highest growth is seen in case of electricity with HHs in the fifth quintile showing an average annual growth of approximately 13 percent. Real per capita expenditures on natural gas is seen to fall for urban HHs while it has increase for rural HHs.

Table 3.6: Average per Capita Real Household Expenditure by Fuel Type and Expenditure

Expenditure quintiles	Electricity		Natural gas		Petrol	
2005-06	Urban	Rural	Urban	Rural	Urban	Rural
First	17.5	9.24	12.91	9.08	4.38	2.76
Second	36.21	20.66	21.08	14.81	48.30	24.77
Third	55.86	31.90	31.23	21.97	59.41	54.82
Fourth	87.13	48.80	46.37	33.59	195.51	101.25
Fifth	157.15	110.05	112.72	86.89	223.45	152.46
2010-11						
First	23.40	10.42	10.97	8.33	6.26	3.40
Second	47.03	22.20	16.91	14.93	50.57	43.57
Third	71.67	35.97	23.14	22.43	91.67	56.49
Fourth	110.16	60.01	34.24	37.45	263.17	126.43
Fifth	297.57	148.59	85.55	104.62	358.90	171.30
2015-16						
First	29.25	18.02	10.29	13.97	6.22	4.52
Second	55.33	34.21	16.31	21.94	51.52	44.12
Third	82.38	52.35	22.87	31.07	77.19	59.58
Fourth	180.90	84.43	35.53	45.41	295.00	185.09
Fifth	324.41	252.94	99.30	125.62	392.69	182.57
Average annual growth rate (%)						
First	6.71	9.50	-2.02	3.50	4.20	6.37
Second	5.28	6.55	-2.26	3.24	0.66	7.81
Third	4.74	6.41	-2.67	2.92	2.99	0.86
Fourth	10.72	7.30	-2.33	2.60	5.08	8.28
Fifth	10.64	12.98	-1.19	2.97	7.57	1.97

Table 3.7 shows that the marginal propensity to consume for the three energy goods for both the urban and rural HHs in all the three years under examination are quite low. The urban HHs are observed to have relatively higher marginal shares as compared to the rural HHs. The marginal expenditure share on these three energy items is seen to be the highest in the year 2005-06 for both rural and urban HHs. According to the results if the HHs increase expenditure per capita by one rupee the urban HHs will spend additional 7.9, 7.8 and 7.1 percent in 2005-06, 2010-11 and 2015-16 respectively. In comparison their

rural counterparts will spend an additional 5.9, 4.6 and 4.3 percent in 2005-06, 2010-11 and 2015-16 respectively. Among the three energy goods, both rural and urban HHs have a higher allocation on electricity during the three sample periods. In comparison to Burney and Akhtar (1990) the marginal budget shares of electricity and gas are higher. This increase can be attributed to the availability of electricity and gas, greater use of electric and gas appliances and village electrification program carried out by the government.

Table 3.7: Marginal Expenditure Shares and Minimum Required Expenditure for Different Fuels

	Marginal Expenditure Share (%)		**Minimum Required Expenditure (Rs.)**	
2005-06	Urban	Rural	Urban	Rural
Electricity	0.043	0.01	59.26	21.94
Natural gas	0.016	0.01	21.94	2.43
Petrol	0.032	0.01	56.29	22.34
Total	0.089	0.05	137.49	46.71
Others	0.90	0.98	1536.43	921.32
2010-11				
Electricity	0.04	0.02	127.21	56.43
Natural gas	0.01	0.01	47.92	5.02
Petrol	0.02	0.01	72.96	36.54
Total	0.07	0.04	248.09	97.99
Others	0.97	0.97	3631.44	1440.52
2015-16				
Electricity	0.03	0.01	132.65	76.34
Natural gas	0.01	0.01	48.07	30.28
Petrol	0.01	0.01	76.26	39.86
Total	0.07	0.03	256.98	146.40
Others	0.97	0.97	4062	2013.47

The inter-temporal analysis of the expenditure of HHs on energy sources shows that the wealthiest HHs spend almost 10 times higher on natural gas and electricity than the poorest HHs. These results are in line with the findings of Iqbal and Nawaz (2020). The monthly expenditure on energy sources have increased with time but are still less than 4% of the HHs total expenditure for the most deprived and less than 6 % for the most affluent section of the society. The per capita expenditures on energy sources also differ across regions.

The spending's of the urban HHs on energy sources is seen to be higher than the rural families.

3.7 Results

The results for the OLS regression are presented in Table 3.8 for the periods 2005-06, 2010-11 and 2015-16. The coefficients are statistically significant during the three years under consideration having anticipated signs. The intercept term for all the three energy sources is positive with small numerical values indicating that all the sources are necessary with low consumption expenditure for the three years under discussion.

Table 3.8: Result of OLS regression.

	Urban		Rural	
2005-06	α	β	α	β
Natural Gas	34.84	0.008	23.63	0.002
	(16.9)*	(10.02)*	(23.80)*	(2.24)*
Electricity	13.47	0.002	8.76	0
	(20.6)*	(10.7)*	(26.23)*	(2.44)*
Petrol and Diesel	22.23	0.006	18.19	0.001
	(9.86)*	(6.88)*	(14.58)*	(10.02)*
Total	0.36	2.05	0.15	4.68
	(21.83)*	(3.06)*	(22.66)*	(7.43)*
Others	4211.93	0.16	3716	0.23
	(28.5078)*	(2.89)*	(48.36)*	(3.39)*
2010-11				
Natural Gas	77.37	0.005	33.36	0.003
	(47.53)*	(7.01)*	(63.25)*	(12.62)*
Electricity	23.52	0	5.96	0.001
	(43.19)*	(8.93)*	(22.24)*	(7.52)*
Petrol and Diesel	52.67	0.005	20.83	0.0001
	(22.88)*	(5.05)*	(26.76)*	(10.02)*
Total	153.57	0.012	60.16	0.004
	(42.56)*	(7.73)*	(22.66)*	(7.43)*
Others	4639.3	0.43	2633.4	0.15
	(42.54)*	(8.99)*	(49.20)*	(5.50)*
2015-16				
Natural Gas	86.91	0.012	39.31	0.0037
	(57.57)*	(23.55)*	(37.04)*	(8.52)*
Electricity	24.23	0.002	2.9449	0.0007
	(50.41)*	(16.17)*	(13.04)*	(8.03)*
Petrol and Diesel	542.7	0.031	280	0.0101
	(41.25)*	(6.78)*	(28.50)*	2.535322
Total	653.85	0.046	322.25	0.014627
	(46.53)*	(9.43)*	(22.66)*	(7.43)*
Others	18691.3	1.64	11323.43	0.60237
	(42.54)*	(8.9)*	(10.02)*	(13.53)*

Note: Figures in parentheses are t-statistics. * Denotes coefficient as statistically significant at the traditional level of significance, i.e., 5 percent.

This is also corroborated by the positive ri* shown in Table 3.7. The coefficients are highly significant statistically during the years under consideration.

The income elasticities are reported in Table 3.10. The numerical value of the income elasticities for all the three years remains positive and below unity, which implies that these energy sources are normal goods for urban as well as rural HHs.

Table 3.9: OLS Diagnostic Test Results

Panel A. Results for Heteroscedasticity						
	2005-06		2010-11		2015-16	
	Urban	rural	urban	Rural	urban	rural
Electricity	0.04(0.99)	0.14(0.75)	3.73(0.65)	0.02(0.97)	9.36(0.49)	6.94(0.52)
Natural gas	0.25(0.12)	0.05(0.81)	0.008(0.92)	1.13(0.28)	3.06(0.92)	9.24(0.24)
Petrol and diesel	2.4(0.61)	0.74(0.38)	1.6(0.34)	0.75(0.38)	2.15(0.97)	1.13(0.07)
Panel B. Results for Normality						
	2005-06		2010-11		2015-16	
	Urban	rural	0.75	0.38	urban	rural
Electricity	5.65((0.34)	1.13(0.59)	0.28(0.98)	1.92(0.76)	1.11(0.89)	0.59(0.63)
Natural gas	2.37(0.66)	1.03(0.90)	8.23(0.09)	5.02(0.34)	9.23(0.48)	3.04(0.97)
Petrol and diesel	9.36(0.49)	6.96(0.52)	2.15(0.93)	10.24(0.23)	2.22(0.09)	1.23(0.45)

Note: Probabilities are given in parenthesis.

The income elasticities for electricity and natural gas is seen to increase over the years in rural HHs which reflects their changing patterns of energy consumption. The decline in income elasticity for electricity for urban HHs in the phase 2005-2011 could be due to the energy shortages resulting in hours of load shedding in the second half of 2000. In the early 2000, there were no supply constraints as electricity was in surplus. In case of petrol the income elasticity is observed to increase both for rural and urban HHs over the three periods under review. This increase may be attributed to the greater usage of vehicles as well as generators due to load shedding.

Table 3.10: Income Elasticities for Different Fuels

	2005-06		**2010-11**		**2015-16**	
	Urban	rural	urban	Rural	urban	rural
Electricity	0.63	0.24	0.41	0.35	0.38	0.40
Natural gas	0.32	0.42	0.27	0.74	0.25	0.83
Petrol and diesel	0.28	0.12	0.34	0.33	0.36	0.54

These results are similar to the findings of Khan et al., 2015; Lin & Zeng, 2013; Gundimeda and Kohlin, 2006) which show that electricity, natural gas and petrol behave as normal goods for rural and urban HHs with a positive income elasticity. However the magnitude of income elasticities varies for different fuels. In case of urban HHs, the income elasticity is highest for electricity in all the three periods indicating that electricity consumption of urban HHs is more responsive to income changes. Whereas in case of rural HHs the income effect is largest for natural gas.

Table 3.11: Uncompensated Price Elasticities for Different Fuels

	Urban			**Rural**		
2005-06	Electricity	Natural gas	Petrol	Electricity	Natural gas	Petrol
Electricity	-0.661	-0.002	-0.006	-0.364	-0.001	-0.002
Natural gas	-0.007	-0.310	-0.008	-0.002	-0.282	-0.002
Petrol and diesel	-0.015	-0.005	-0.253	-0.002	-0.001	0.110
2010-11						
Electricity	-0.444	-0.002	-0.007	-0.616	-0.001	-0.002
Natural gas	-0.009	-0.211	-0.008	-0.006	-0.240	-0.003
Petrol and diesel	-0.010	-0.003	-0.143	-0.001	-0.006	-0.207
2015-16						
Electricity	-0.505	-0.001	-0.002	-0.557	-0.001	-0.026
Natural gas	-0.007	-0.371	-0.078	-0.009	-0.413	-0.059
Petrol and diesel	-0.010	-0.003	-0.231	-0.001	-0.001	-0.162

The uncompensated own and cross price elasticities are given in Table 3.11. The price elasticities of all three energy sources have anticipated negative signs in all three years under discussion. The magnitude of these elasticities is observed to be small indicating that the consumption in both urban and rural HHs is not much responsive to the changes in prices. These estimates are similar to the findings in the literature (Athukorala and Wilson, 2010; Gebreegziabher, et al., 2010; Sene, 2012). Although the magnitude of these price elasticities are small, it has been observed that electricity which has the highest budget share among the three energy sources has the highest own price elasticity. This results are consistent with findings of Nigui et al., (2012), showing that the category of fuel which has the largest budget share is more responsive to price changes as HHs respond more by increasing or decreasing the expenditure share on the respective fuel category.

3.8 Conclusion and Policy Implications

The aim of this study has been to analyze the household expenditure patterns on three main energy sources i.e., electricity, natural gas and petrol in response to the increasing energy prices by using three sets of micro data for the years 2005-06, 2010-11 and 2015-16. The income and price elasticities of these sources have been computed using Extended Linear Expenditure System. In addition the household expenditure patterns on these energy sources have been analyzed for different expenditure quintiles of urban and rural HHs. Quintile wise household per capita expenditure witnessed a rise in electricity, natural gas and petrol for both urban and rural HHs during 2006-16, however the growth in per capita expenditure in these energy sources is observed to be higher in case of rural HHs.

The marginal budget shares of all the three sources have been found to be on lower side across the three periods for both urban and rural HHs. The marginal budget shares of the urban HHs are seen to be relatively higher than the urban counterparts. The income elasticities of all the three sources are found to be less than unity, indicating that all the three sources behave as normal goods. Due to the small magnitude these results show that households do not increase their consumption of these energy sources significantly with the rise in their income. The price elasticities are found to have the expected negative signs with low magnitudes indicating they are less responsive to changes in price. The low price elasticities indicate that as the prices of these energy sources fall, there will not be a proportional increase in the demand of these sources.

The results of these demand elasticities indicate that both urban and rural households consume energy (electricity, gas and petrol) according to their needs. The prices of all the three sources have changed in the years under consideration with increasing prices of gas and electricity and fluctuating prices of petrol yet the demand elasticities have remained low for all the three periods. It has also been observed that the petrol prices in Pakistan do not necessarily fall with the decline in international oil prices. The prices of petrol were reduced at the end of 2014 in response to the falling international oil prices but were immediately increased due to the artificial shortage of fuel. Hence, targeting energy subsidies in order to reduce the fiscal burden may be a suitable policy by the government. However, such a decision should be carefully designed as it will adversely affect the poor.

Chapter 4
Electricity Subsidies in Pakistan and Welfare Impact of Policy Reforms

4.1 Introduction

Energy subsidies are considered as an important part of macroeconomic policy by government especially of the developing countries to attain economic and social targets. Subsidies are a means of poverty alleviation and economic development as they enable access to affordable energy services and improve living standards of the poor (Lin and Kuang, 2020; Lin and Chen, 2018; Rahmati and Karimirad, 2017). The International Energy Agency (IEA, 1999) and Organization for Economic Co-operation and Development (OECD, 1998) have defined subsidies as "any government action that raises the price received by energy producers, lowers the cost of energy production or lowers the price paid by energy consumers". The global energy subsidies reached US$5.3 trillion i.e. 6.5% of global GDP during 2015 (Coady et al., 2015). However, recently the momentum of phasing out energy subsidies has gained pace due to their failure of meeting the intended objectives[12] (IEA and OECD, 2010). There is extensive literature revealing that energy subsidies are the most regressive and costly policies, especially in case of developing countries (The World Bank, OECD & OPEC 2010). A recent analysis by OECD shows that energy subsidies not only impose a significant burden on states budget but also encourage inefficient consumption of energy leading to more carbon emission. Recognizing the inefficiency of these subsidies, they are being eliminated by various countries (Clements et al., 2013).

[12] Protecting the poor against high energy prices and providing them affordable energy.

In the past decade, Pakistan has been spending more than 2 percent of its GDP on electricity subsidies, which not only increased national debt but also weakened the country’s external position. Electricity subsidies accounted for almost 8 percent of net revenue in 2020 (Budget in Brief, 2021). In order to cover the cost of electricity production at least Rs.3 is paid by the government on every Kwh consumed by the domestic user (Awan, et. al, 2019). Energy subsidies particularly electricity subsidies have become a serious issue for Pakistan as there is already shortage of energy supply. The targeting mechanism of the tariff structure is based on the principle that the household welfare is determined by the amount of electricity consumption. But in case of Pakistan, this correlation between household welfare and electricity use is relatively weak as the subsidies continue to benefit the rich HHs disproportionately (Walker et al., 2017). Due to the strong seasonality present in electricity consumption the poor HHs are pushed into the higher-tariff slabs during summers whereas, many rich HHs fall into the highly subsidized and lifeline slabs during the winters (Feltenstein and Datta, 2020). In such a situation the removal of electricity subsidies will arguably release the pressure on fiscal budget and will create resources for more equitable social spending but consequently it will raise the prices of electricity which will affect the welfare (consumption) of poor adversely. Therefore, in order to determine the impact of phasing out subsidies, there is a need to analyze how well the poor are targeted through electricity subsidies? For this analysis it is necessary to determine what is the amount of subsidies received by each income group?

Moreover, the effect of removing electricity subsidies will have different impact on different consumer groups (residential, commercial, industrial and agriculture). This chapter aims to quantify the size of electricity subsidy for each sector and assess the potential impact of subsidy removal on electricity consumption by each sector (residential, commercial, industry and agriculture) before and after the policy reform. In case of Pakistan the impact of subsidy has been analyzed only for the domestic sector. This chapter seeks to compute the quantity of subsidy given to each sector and analyze the extent of cross subsidization present among these sectors. It also analyzes the impact of phasing out subsidies with the application of price gap approach. Furthermore, it aims to do a benefit incidence analysis to compare the amount of subsidies different income group receive before and after the 2013 policy reform. Following Trimble, Yoshida & Saqib (2011), the benefit incidence analysis is carried out for the year 2012 and 2015 in order to determine how successful the policy reform has been in targeting the poor HHs. This analysis will not only determine how efficiently the electricity subsidy is targeted toward the poor but it will also provide information about the leakage from the intended beneficiaries to others. The welfare impact of residential electricity subsidies has not been paid much attention in Pakistan. There are only a few studies that have investigated this issue in case of Pakistan. All of these studies have concluded that a targeted tariff structure has to be implemented in order to protect the poor. However the impact of a targeted tariff structure on household welfare (electricity consumption) and on the subsidy received by different income quintiles has not been analyzed so far. In order to do so this chapter analyzes the impact of two scenarios i.e. a uniform and a non-uniform increase in the tariff structure on the subsidy distribution and household welfare. We analyzed the impact of both policy changes in order to understand the effectiveness of such policy reforms for providing protection to the poor.

4.1.1 Objectives of the study

The broad objectives of this chapter are as follows:

- To analyze the extent of cross subsidization among sectors and within different user groups of residential sector.
- To analyze the impact of electricity price reform on consumer welfare through benefit incidence analysis.

4.1.2 Significance of the study

This study also seeks to analyze how efficiently the electricity subsidy is targeted towards the poor, providing information about the leakages from the intended beneficiaries to others. The welfare impact of residential electricity subsidies has not been paid much attention in Pakistan. There are only a few studies that have investigated this issue (Walker et al., 2017; Khalid & Salman, 2019; Awan, Samad & Faraz, 2019) in case of Pakistan. All of these studies have concluded that a targeted tariff structure has to be implemented in order to protect the poor. However the impact of a targeted tariff structure on household welfare (electricity consumption) and on the subsidy received by different income quintiles has not been analyzed so far. In order to do so this study analyzes the impact of two scenarios i.e. a uniform and a non-uniform increase in the tariff structure on the subsidy distribution and household welfare.

4.1.3 Organization of the Study

The rest of the chapter is organized as follows. Section 4.2 discusses the tariff structure of electricity, section 4.3 gives the literature review, Section 4.4 analyzes the theoretical framework, Section 4.5 explains data, Section 4.6 explains the electricity consumption by different sectors, Section 4.6 delves into the results while Section 4.7 concludes the chapter.

4.2 Electricity Tariff Structure

According to the Pakistan Economic Survey 2016 the tariff setting process involves the following steps: "(1) DISCOs send their tariff proposals to NEPRA justifying their costs and revenue requirements, (2) NEPRA sets tariffs for various category of consumers for each DISCO based on its own assessment of costs and revenue requirements which can differ from the ones provided by DISCOs, and communicates it to the MoWP with the recommendation to notify the tariff, (3) The Ministry of Water and Power (MoWP) notifies a tariff schedule for the different categories of consumers, which is common across all DISCOs." The MoWP sets a common tariff for all DISCOs, though the tariffs approved by NEPRA vary across DISCO's. The difference between the allowable cost of electricity determined by NEPRA (National Electric Power Regularity Authority) and the electricity tariff with certain charges paid by the consumer determined by the MoWP is known as the tariff differential subsidy (TDS). Figure 4.1 shows different tariff rates proposed for different distribution utilities but government applicable rate is uniform for each DISCO. The Tariff Differential Subsidy (TDS) is the largest electricity subsidy provided by the government which constitutes 96 percent of the total electricity subsidies (World Bank Report, 2017).

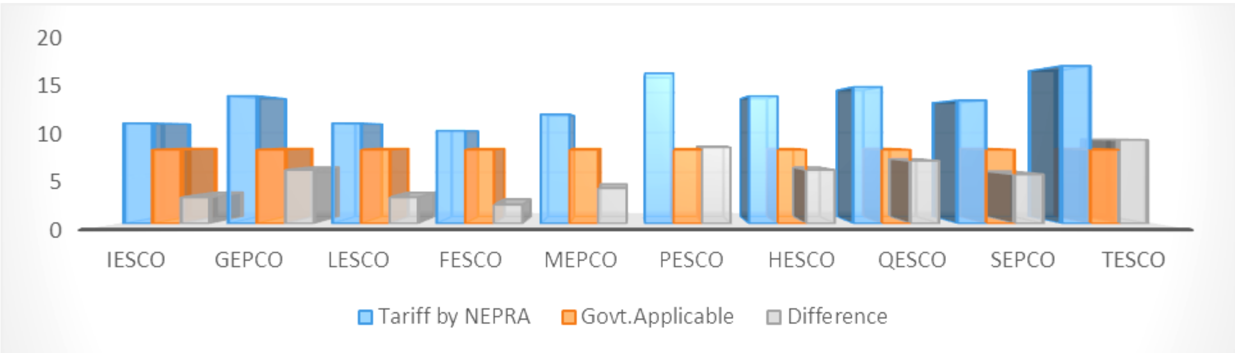

Figure 4.1: Tariff difference between Discos and Government

Source: Pakistan Economic Survey 2018-19.

The government of Pakistan has taken several reforms in the power sector. As a part of its reforms the government has increased electricity tariffs for the residential consumers and eliminated subsidies for commercial and industrial consumers in October 2013 (World Bank, 2016). The main targets of the power policy 2013 (National Power Policy 2013, GOP) were:

1. Target the power subsidies directly for the poor.
2. Increase the cost of electricity for the consumers utilizing generators and confined power.
3. Phase out subsidies over a period of three years.
4. Cross subsidize the residential sector at the cost of industrial and commercial sector

However, the government continued paying more than Rs.1 trillion in the form of Tariff Differential Subsidy (TDS) in order to protect consumers against the increasing cost of electricity during 2013 (Ministry of Finance, Government of Pakistan, 2013).

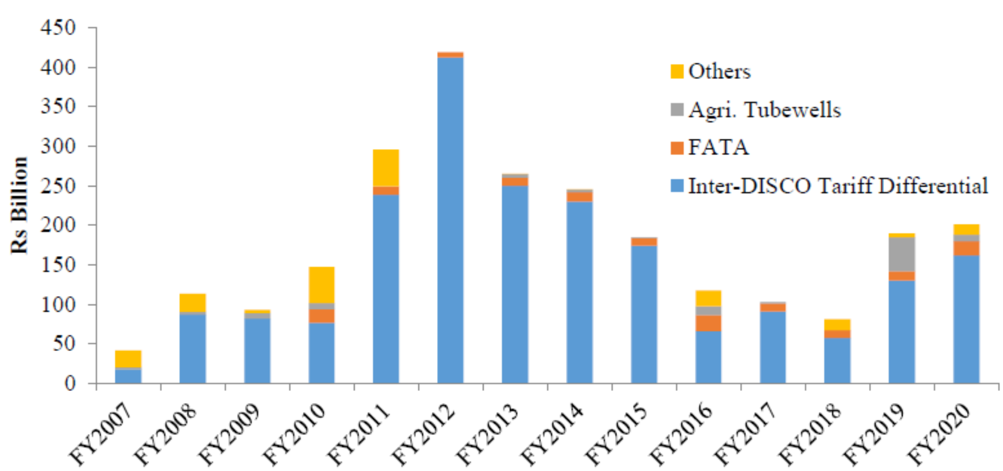

Figure 4.2: Subsidies to WAPDA/PEPCO

Source: Budget In Brief (2007-21)

Different Tariff rate are approved by NEPRA for various consumer categories like residential, commercial, industrial and agricultural. There are other categories as well that purchase electricity in bulk to distribute it further. The consumer categories are also distinguished with respect to load requirement and are charged accordingly. The tariff schedule is also distinguished according to the time of consumption i.e. peak and off peak. The MoWP also sets tariff schedule for each category of consumers at a lower rate than NEPRA. Figure 4.2 shows the trend of average variable tariff rates for the Residential, Commercial, Industrial and Agriculture sectors determined by GOP.

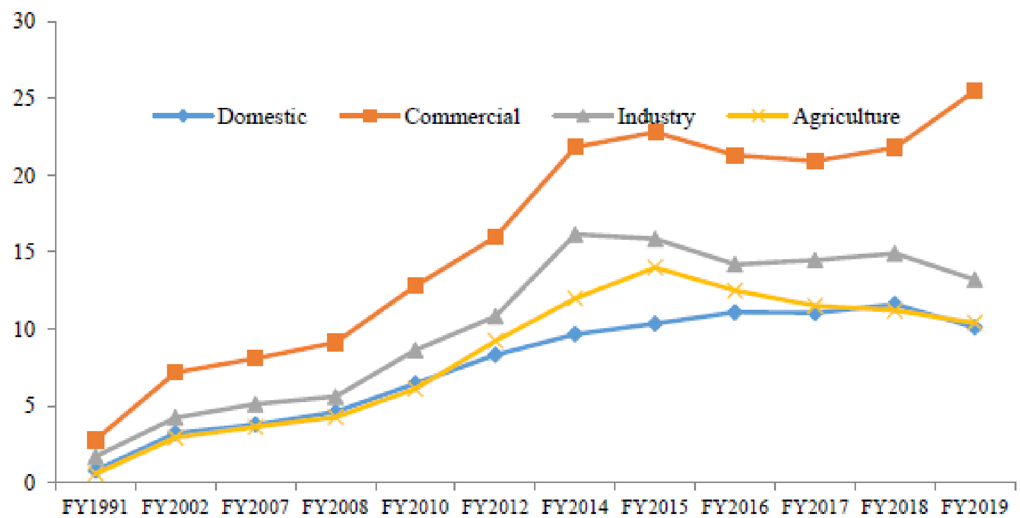

Figure 4.2: Average Tariff Rates (Government of Pakistan

Source: Afia, 2021

Figure 4.2 shows that the industrial and commercial sector pay higher rate of electricity tariffs than the residential and commercial sectors. Substantial subsidies to the residential sector leads to more electricity consumption and reduces incentives to conserve energy. The residential tariffs are much lower than the supply cost which results in low energy efficiency. The tariff structure for the residential users is based on incremental block tariff (IBT) structure. The unit cost of electricity increases from one slab to the next as it is shown in Table 4.1 for the residential use[13]:

Table 4.1: Electricity Tariff Structure (Residential consumers)

Monthly consumption (kWh)	22/3/2018
0-50*	2
1-100**	5.79
101-200	8.11
201-300	10.20
301-700	16
700+	18

Note:* Lifeline rate below consumption of 50kWh/ month

**This rate is paid for the first 100 units.

Households (HHs) which use less than 50 kWh/month are provided with a Lifeline tariff so a minimum amount of electricity is delivered to the poor HHs[14]. In 2013 the government switched from "all slab benefit" structure to "previous slab benefit" increased the tariff rates for slabs directly above 200 kWh/month by dividing the second slab (101-300 kWh) into two slabs (i.e. 101-200 kWh and 201-300 kWh). According to the new tariff there is no subsidy given to the top 2 slabs, however due to the second slab (i.e.201-300 kWh) some HHs still benefit with a small amount of subsidy. The consumers having their consumption usage above 300kWh are benefitting from the subsidies given in the lower slabs.

[13] This the standard tariff notified by the government. There are flat peak and off peak charges for users with electronic meters (implemented from June, 2015).

[14]The minimum amount charged for a single phase connection is Rs.75.

4.3 Literature Review

There is a large number of studies on energy subsidies and the impact of subsidy reforms on production, consumption, welfare etc. Estimating the quantity of energy subsidies De Moor (2001), found the subsidies received by the energy sector amounted to $240 billion. Riedy and Diesendorf (2003) estimated that the amount of energy subsidies summed up to be $6.54 billion in case of Australia. IEA (2006) calculated the world subsidies to be 0.6% of the worlds GDP i.e. $280 billion in 2005 which increased to $310 in 2007. According to Morgan (2007) majority of these subsidies were directed to lower energy prices for consumers. Analyzing the impact of energy subsidies many studies such as Dube (2003) and Kebede (2006) concluded that the energy subsidies were not able to make energy cheaper for poor. Chattopadhyay (2007) found that the electricity subsidies were cross subsidized for the domestic sector which not only increased the inefficient use of electricity but also were not effective for providing cheaper electricity to the poor.

Saunders and Schneider (2000), analyzed the impact of removing energy subsidies and found that removing subsidies will make energy more costly reducing its consumption and in case of countries that produced energy, the export of energy will increase. Burniaux et al. (2009) estimated the impact of removal of fuels and electricity subsidies gradually for 20 non-OECD countries and concluded that removal of subsidies would bring down the level of carbon emission. The demand for the energy exporting countries will reduce pushing the international energy prices downwards. This will in turn raise the demand by energy importing countries. Ouyang and Lin (2014) showed that removing energy subsidies by only 10% reduced the negative impact on economic growth (GDP) from 4% to 0.4% in case of China. By phasing out energy subsidies the energy conservation amounted up to 7% of energy consumption during 2010.

On the other hand most of the studies of energy subsidy reform and impact on household's welfare show that the impact of energy subsidy removal is regressive (Coady et al., 2017; Clements et al., 2014). For example, Saboohi (2001) concluded that decreasing subsidies in Iran will raise the cost of living for poor HHs (28.7 percent for urban HHs and 33.7 percent for rural HHs). Another study by Andriamihaja and Vecchi (2007) analyzed the impact of fuel price increase on the living standard of HHs for Madagascar. Their results clearly showed that subsidies benefit the rich more as compared to the low income HHs. Similarly Leigh and El Said (2006) found that most of the subsidies in Gabon helped the HHs of higher income groups instead of the HHs in lower income groups. A study by the World Bank (2008) conducted for developing countries shows that the lowest income groups receive only 15 to 20 percent of the fuel subsidies. Another study by the International Monetary Fund gave evidence that 80% gasoline, 65% diesel and 70% LPG subsidies goes to the richest 40 percent of HHs. Lin and Jiang (2009) found that low income HHs of China received only 10 percent of the total electricity subsidies while the higher income groups of HHs received 5 percent of the total electricity subsidies. A joint report on the impact of subsidy reform in OECD and non-OECD countries showed that subsidy reforms in Poland, Indonesia, Malaysia and the U.S. have led to decrease in inflation, increase in household's disposable income and decrease in energy consumption (IEA, OPEC, OECD and World Bank, 2010). Zhang (2011) analyzed the distributional impact of electricity pricing reform for Turkey and found that the welfare loss was higher in case of the low income quintiles. Some studies have also revealed that the welfare impact were neutral or progressive. Kebede (2006) showed that subsidies on electricity tariff and kerosene oil did not change the household expenditure significantly in case of urban HHs of Ethiopia.

The literature related to impact of electricity subsidy removal can be classified into two groups (a) studies related to the distribution of electricity subsidies and (b) studies analyzing the welfare impact of electricity policy reform. Evidence from the developing country suggest that the higher income groups benefit more from the distribution of electricity subsidies than the lower income groups. Though, the estimate of impact varies across countries. For example Banerjee et al. (2008) gave evidence that only 0.5% of the total electricity subsidy reach the poor HHs in Rwanda whereas, this estimate was 9% in case of Ghana and 3 percent in case of Burkina Faso. Komives et al., 2009, show that the richest HHs receive four times more electricity subsidies as compared to the bottom 10 percent of the HHs. Bangladesh and Pakistan also showed similar results with 6 and 3 times more subsides going to the richest HHs respectively Ahmed et al., 2013; Trimble et al., 2011). Similarly Wang and Zhang, 2016, found it to be 5 times higher than the bottom 10% of HHs. In case of Zambia the electricity subsidies were also found to be regressive with only 2% of subsidies going to the bottom 50% of HHs (Fuente et al., 2017).

Most of the literature related to electricity price reforms concludes that removal of subsidies has a negative impact on real household welfare. Lin, Jiang and Lin (2011) analyzed the welfare impact of removing subsidy on electricity in China. They found that the welfare loss of subsidy removal was more for poor HHs as compared to rich HHs. In 2015 the percentage loss in real income of the poor HHs was estimated to 2 times larger than the richest HHs (Jiang et al., 2015). Zhang, 2015 showed that a 50 percent increase in electricity prices of Turkey brought about 3 times more percentage reduction in incomes of the poor HHs relative to the higher income HHs. Similar results were also observed in 8 out of 10 countries in Latin American and the Caribbean by Feng et al., (2018) where the income loses of the poor were larger in comparison to the rich.

Very few studies have evaluated the welfare impact of subsidy reform in case of Pakistan. Walker, Canpolat, Khan & Kryeziu (2016, 2017) estimated the likely impact of policy reform on household welfare by using poverty scores measure and stimulated the effects of various compensating methods like direct cash transfers. Their results suggest that the electricity subsidies benefit the rich more as compared to the poor. Using a national proxy means test (PMT) they concluded that targeted subsidies can be a better means to ensure assistance to the needy HHs. Khalid & Salman, (2019) determined the optimal level of electricity by computing the dead weight loss of consumer welfare due to a uniform and non-uniform price increase of electricity. They also concluded that targeted subsidy approach improves the welfare of the poor HHs. Awan, Samad & Faraz, (2019) used Social Accounting Matrix (SAM) 2010-11 and IFPRI to develop Computable General Equilibrium (CGE) Model in order to assess the welfare impact of direct transfer mechanism of Tariff Differential subsidy (TDS). Their study revealed that TDS does not provide relief to the poor instead it benefits the rich segments of the society. They suggested that the Tariff Differential Subsidy has to be phased out or be made more targeted. Their study also suggested that reducing TDS will ease out financial hardships of the government by reducing fiscal deficit.

The literature on energy subsidies and the impact of energy subsidy reforms suggests that energy subsidies contributes to the inefficient use of energy. However, reducing these subsidies has adverse effects on the poor HHs. This chapter contributes to the literature by analyzing in detail the subsidies received by different sectors of the economy and assess the potential impact of subsidy removal on electricity consumption by each sector, before and after the policy reform. Furthermore, it aims to do a benefit incidence analysis to compare the amount of subsidies different income group receive before and after the 2013 policy reform.

4.4 Theoretical Framework and Methodology

This section has been divided in three subsection. The first subsection gives the theoretical frame work while the methodology used to evaluate the impact of subsidy removal on economic sectors has been discussed in the second subsection and the methodology used to estimate the impact of subsidy removal on household welfare has been given in the third subsection.

4.4.1 Theoretical Foundation

To estimate the impact of removing electricity subsidy on each sector this study makes use of the price gap approach. Corden (1957) gave the theoretical foundation of the price gap approach which relied on the premises that subsidies cause a higher consumption of energy. In this study, we first compute the subsidies by estimating the price gap for each sector (domestic, commercial, industrial and agriculture):

$$\text{Price gap} = \text{Consumer price} - \text{reference price} \qquad (4.1)$$

Where the reference price is the cost of producing electricity and consumer price is the subsidized price paid by each sector. The reference price is calculated by taking the average of supply cost of all the independent power stations and generation companies (GENCOS) given in the State of Industry report, NEPRA for the year 2012 and 2015. The quantity of subsidies received by each sector is then calculated by multiplying the price gap with the quantity of electricity consumed by each sector.

Energy Subsidies= price gap × energy consumption (4.2)

4.4.2 Impact of Energy Subsidy Removal on each Sector

The impact of phasing out subsidies is dependent upon the functional form of the demand function. Following IEA (1999), we adopt a constant elasticity inverse demand function which is given as:

$$Q_i = P_i^e \tag{4.3}$$

Where, Q is the amount of electricity consumed by each sector "i" and P is the price of electricity and e is the price elasticity of demand for that sector. The price elasticity of demand for each sector has already been estimated in chapter 3 for each sector. For each sector the quantity consumed after the removal of subsidy is calculated as:

$$\ln Q_1 = \varepsilon \times (\ln P_1 - \ln P_0) + \ln Q_0 \tag{4.4}$$

The impact on consumption is established as:

$$\Delta q = Q_0 - Q_1 \tag{4.5}$$

Here, Δq is the decrease in consumption if the price gap is removed: ε is the long term demand elasticity, P_0 and Q_0 are the price and quantity before the removal of price gap and P_1 and Q_1 are the price and quantity after the removal of price gap respectively.

4.4.3. Impact on Household Welfare

In most of the studies on impact of subsidies on HH welfare the household welfare has been related to the quantity of electricity consumed by the HH. However, in case of Pakistan it has been seen that household welfare is weakly related to the electricity use, as the subsidies continue to benefit the HHs belonging to rich income groups. We have therefore estimated the impact of electricity subsidy on household welfare by first comparing the benefit incidence of electricity before and after the electricity reform 2013. The PSLM survey data for the year 2011-12 and 2015-16 has been used. Following Trimble et al., (2011), the subsidy (benefit incidence) received by each income group has been calculated as under:

$$S = C - E \tag{5.6}$$

$$C = U \times Q \tag{5.7}$$

$$Q = \frac{E}{T} \tag{5.8}$$

Where S is the amount of subsidy, C is the cost of electricity supply that is calculated as the average cost of supply by all the power stations[15], E is the electricity expenditure, U is the unit cost of supply, Q is the quantity of electricity consumed and T is the tariff rate.

The quantity of electricity consumption has been calculated from the expenditure data. First the HHs were divided among different slabs using the tariff structure of 2012, for example if the expenditure of a HH is Rs. 150, their electricity consumption belongs to the first slab with a tariff rate of Rs.2. Once the slabs are identified to which the HHs belong to, the quantity of electricity consumed is calculated using the variable tariff rate i.e. {(total expenditure- expenditure on the previous slab)/tariff rate of the current slab} + quantity consumed in the previous slab. For example if the expenditure of a HH is Rs.2500 then it belongs to the fourth slab and its consumption is computed as (2500-2201)/12.33 +300.

[15] The average cost of supply for 2012 is Rs. 9.47 and for 2015 is Rs.12. State of Industry Report 2015, Nepra.

Applying the GST[16] of 17% to consumers using more than 100 kWh per month, and a 1.5 percent excise duty, the net subsidy is calculated as:

$$N = S - T \tag{5.9}$$

Where N is the set subsidy. We assume that HHs do not change their electricity expenditure in response to any revisions in the tariff structure during 2012.

Similarly the IBT structure and average cost of electricity supply were used to estimate the quantity consumed by HH in 2015. The IBT, average cost of supply and the expenditure on electricity by HHs have been adjusted for inflation to enable comparability with 2012. By applying monthly inflation rate the nominal to real price reduction has been estimated to be 18% using monthly price statistics data given by Federal Bureau of Statistics (FBS).

4.5 Data

The data for electricity consumption by sectors and Tariff structure is taken for the energy year book 2012 and 2015. The household expenditure on electricity data is taken from the PSLM survey 2012 and 2015. The cost of supply of electricity by different power stations is taken from the State of Industry Report by National Electric Power regulatory Authority (NEPRA) 2012 and 2015.

4.6 Electricity Consumption by Economic Sectors

The electricity demand has grown immensely over the years. Pakistan total electricity consumption for the year 2012 was 77165050 kWh. Of the total consumption 27.5% was consumed by industry, 47% by residential, 14% by commercial and 14.3% by agricultural sector. While in 2015 the total consumption of electricity was 90434880 kWh, out of which

[16] Consumer end applicable tariff, NEPRA 2012.

27.6% was consumed by the industrial sector, 49% by residential, 13.6% by commercial and 9% by the agricultural sector. This shows that after the policy reform 2013 the residential consumption has increased by 2 percent while that of commercial sector and agriculture has decreased. The industrial consumption has not shown any change in the two years. A comparison of customers class-wise (Residential, Commercial, Industrial and Agriculture) average rates and average subsidy worked out based on NEPRA[17] determined rates (average of all the Discos) and GOP notified rates before and after the reform (May 16, 2012, June 10, 2015) is tabulated below in Table 4.2:

Table 4.2: Tariff Difference between NEPRA and Government rates

	2012			**2015**			**% increase in Tariff (GOP)**
Sector	NEPRA	GOP	TDS	NEPRA	GOP	TDS	
Residential	11.64	8.66	2.98	12.20	10.01	2.19	15.59
Commercial	15.86	12.24	3.62	15.73	17.00	-1.28	38.89
Industry	12.80	10.28	2.52	14.14	14.95	-0.81	45.43
Agriculture	11.16	7.84	3.32	13.52	11.09	2.43	41.45
Average cost of electricity Supply	9.47			12			

Table 4.2 clearly shows that the agriculture and residential sectors pay less tariffs as compared to the industrial and commercial sectors in both the years. Industrial and commercial sectors are paying more than the average cost of supply in 2012 and 2015. This shows that the government is subsidizing the residential and the agriculture sector at the cost of higher tariffs for the industrial and commercial sectors. The increase in tariff for

[17] The detail tariff structure by each Disco is given in the appendix (A).

residential sector is 16%, 39% for commercial, 45% for industry and 41% for agriculture sector. The tariff rate notified by the government for the residential sector for the year 2012 and 2015 are given in Table 4.3[18] . After the policy reform 2013, the government has increased tariffs for slabs above 200 kWh /month (thereby dividing the second slab in two) and changed the method of calculating bills as shown in Table 4.3. Whereas before HHs paid for the first 100 units at the 1-100 kWh/month slab rate, the next 200 at the 101-300 kWh/month slab rate and so on.

Table 4.3: Electricity Tariff Structure for Residential Users, Nominal Prices (June 2012, 2015)

Monthly consumption (kWh)	Tariff Rate (June 2012)	Tariff Rate (June 2015)	% increase
0-50*	2	2.00	0
1-100**	5.79	5.79	0
101-200		8.11	0
201-300	8.11	10.20	26
301-700	12.33	16.00	30
700+	15.07	18.00	19.44
Average Cost of Electricity Supply	9.47	12	27

Source: Pakistan Electric Power Company (PEPCO).

Figure 4.3 shows that the average tariff at different levels of electricity consumption and how it has changed in real terms between June 2012 and June 2015. While the tariff rates have increased for only the last 3 slabs in nominal terms, they have decreased for the lower slabs in real terms with a slight increase for third and fourth slab (201-300kWh/month and 301-700kWh/month). This means that the policy reform 2013 has targeted those 32% consumers which consume electricity up to 200kWh/month as shown in figure 5 (8 % consumed in the 1-100kWh/month block, 24% consumed in the 101-200kWh/month

[18]For this analysis, we use data from State of Industry report 2015 by NEPRA.

block, 32% consumed in the 201-300kWh/month block, 29% consumed in the 301-700kWh/month block and 7% consumed above 700kWh/month). However, there has been no real increase in the electricity tariff for the highest slab.

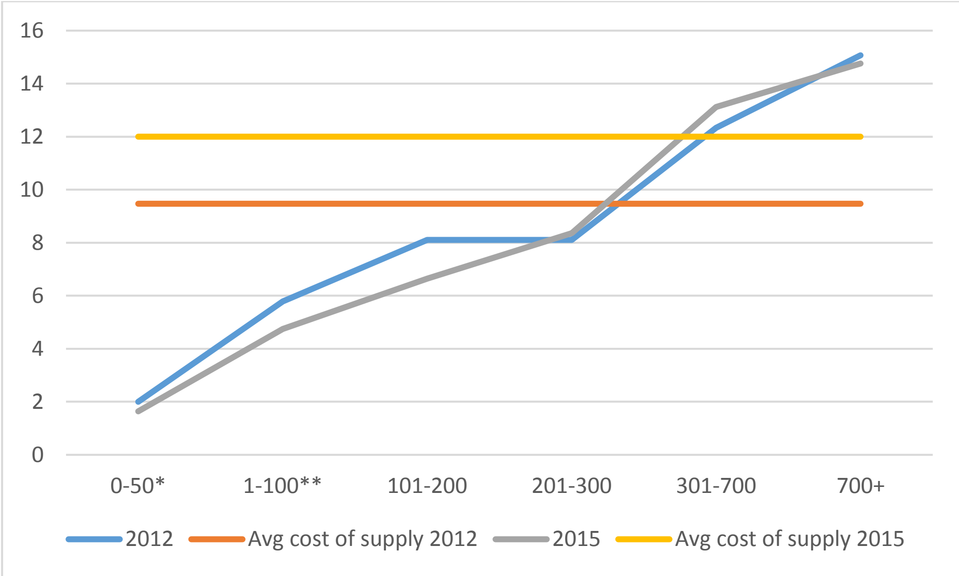

Figure 4.3: Average Tariff for Varying Levels of Electricity Consumption, in June 2012 prices

The unit cost of electricity charged is greater than the average cost of electricity supply for the highest two slabs in both of the years (2012 and 2015). This means that there is cross subsidization taking place between high volume and low volume customers. However, the extent of cross subsidization is dependent on the volume of consumption at the higher slabs. In 2012 the volume of consumption by the upper two slabs is 28% of the total electricity consumption and for 2015 its 36% (shown in Figure 4.4). This shows that the extent of cross subsidization among the high and low volume customers is limited in both of the years.

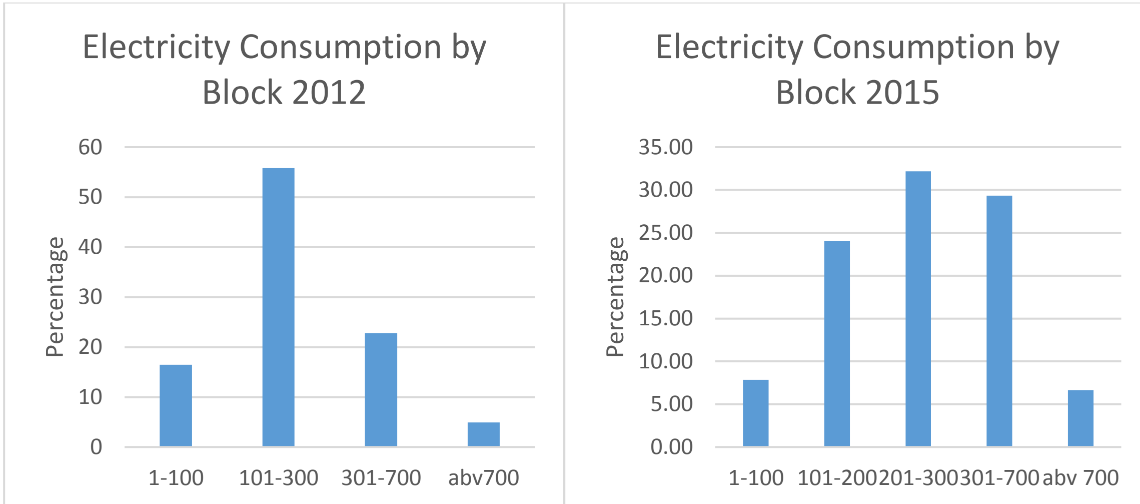

Figure 4.4: Electricity Consumption by block 2012, 2015.

4.7 Results

This section has been divided in three subsection. The first subsection gives the calculation of reference price and price elasticities used to evaluate the impact of subsidy removal on economic sectors, the second subsection gives the results for the impact of subsidy removal on economic sectors and the third subsection gives the results for the impact on household welfare.

4.7.1 The reference price and Price elasticity of demand

The reference price has been estimated by taking the average of supply cost across all the power generating units. The detailed table for the supply cost of these power stations for the year 2012 and 2015 is given in the appendix (Table A6). While, the price elasticity of demand for electricity has already be computed in chapter 3 for all the four sectors and is given in Table 4.4.

Table 4.4: Price elasticities of demand for Electricity

Sector	Price elasticity
Residential	-0.41
Commercial	-0.06
Industry	-0.16
Agriculture	-0.74

These elasticities reveal that the agriculture sector is the most responsive to the changes in price of electricity, while the commercial and industry sector do not respond proportionally to the price changes. It can be seen that only agriculture sector has reduced its consumption from 14% to 9% of the total electricity demand after the increase in tariff. While industry and commercial sector had minor decrease in their consumption. On the other hand the consumption by the residential sector has increased by 2% despite the rise in prices. This rise can be due to the increase in electricity supply connection provided by the government under the electrification program as discussed in the previous chapter. Moreover the subsidy for the residential sector has not decreased by a significant amount which causes the residential sector to increase its consumption which increases the inefficient use of electricity.

4.7.2 Impact of removing Subsidy

Based on the tariff structure (Table 4.2), we estimate the price gap by subtracting the average cost of supply from the government notified tariffs. Using the elasticities given in Table 4.4 and the constant elasticity inverse demand function given in equation 4.3, the energy consumption after the removal of price gap and the difference in the quantity consumed before and after the removal of subsidy is calculated. The results for both of the years 2012 and 2015 are presented in Table 4.6. The detail of this analysis is given in the appendix (Table A7).

Table 4.6: Electricity Subsidies and effect of removing subsidies

Sector	**Subsidy (Million Rs.)**	**Share of Subsidy in GDP (%)**	**Potential Energy saving due to subsidy removal (kWh)**
2012			
Residential	28,827	0.30	1281060982
Commercial	-15,938	-	-89267170
Industry	-17,658	-	-288165882
Agriculture	13,933	0.14	1115080738
Total	42,760		2396141720
2015			
Residential	87002	0.81	3132358644
Commercial	-35510	-	-149982183.9
Industry	-73691	-	-894146064.6
Agriculture	7758	0.07	483324427.3
Total	94761		3615683072

Table 4.6 indicates that the residential sector gets the largest share of subsidies in both years which increases the inefficient use of energy. By removing the electricity subsidies in 2012, the electricity consumption by the household sector will decline by 4%, and agricultural electricity consumption will reduce by 13%. Since the commercial and the industrial sector are paying more than the average cost of supply their consumption will increase if the charged tariff is set equal to the average cost of supply. The consumption of the commercial sector will increase by 1.5% and that of industrial sector will rise by 1.3%. While in 2015, after the policy reform the tariff differential subsidies for the residential sector have decline by 9.9%. The tariff rate for the residential sector has increased by Rs. 1.35. Whereas removing the electricity subsidies will decrease the electricity consumption of the residential sector by 7.2% and that of agriculture sector by 6%. The tariff notified by the government for the commercial and industrial sector is greater than the average cost of supply which has increased the average tariff for the commercial sector by Rs. 4.76 (39%) while that of the industry sector has increased by Rs. 4.67 (45%). These results gives

evidence of cross subsidization for the residential sector at the cost of higher tariffs for the commercial and industry sector. However, the extent of cross subsidization still remains unclear as the variable charge for B1 and B2 (indusrial Tariffs is smaller than the charges for 301–700 unit residential slab. Due to the unavailability of information about the units of electricity consumed above 700KW and units consume in the B1 and B2 slabs of industrial sector the estimated difference between the negative subsidy for commercial and industrial sector an positive subsidy for residential and agriculture sector, is quite large.

The high tariff rates for the commercial and the industrial sector will bring a decline in the economic activity as the productivity of these sectors will surely be effected by high prices of electricity. If the tariff rates were set equal to the average cost of supply of electricity, consumption of the commercial sector would have increased by 2.1% and that of industry would have been increased by 3.6%. By removing the electricity subsidy 3.12% of the total electricity consumption will be saved for the year 2012 and 4.04% will be saved for the year 2015. These results shows that potential energy can be saved by phasing out electricity subsidies but this would harm the welfare of HHs specially the HHs belonging to lower income quintiles. The following section shows the impact of increasing tariff rates on the welfare of HHs belonging to different income quintiles.

4.7.3 Welfare Analysis

The results of the benefit incidence analysis for 2012 and 2015 is presented in Figure 4.5. Although Pakistan's tariff structure provides a low price to the low volume consumers, the poor HHs (HHs in q1) are not the highest beneficiaries of electricity subsidies in 2012. It is clear that the HHs falling in the fourth and fifth income quintile are the biggest beneficiaries from the subsidies. The poorest HHs on the other hand which are the main target of the IBT structure received less than 5% of the subsidies provided by the government while the richest 20% of the HHs are the biggest beneficiaries receiving 25% of the total subsidies.

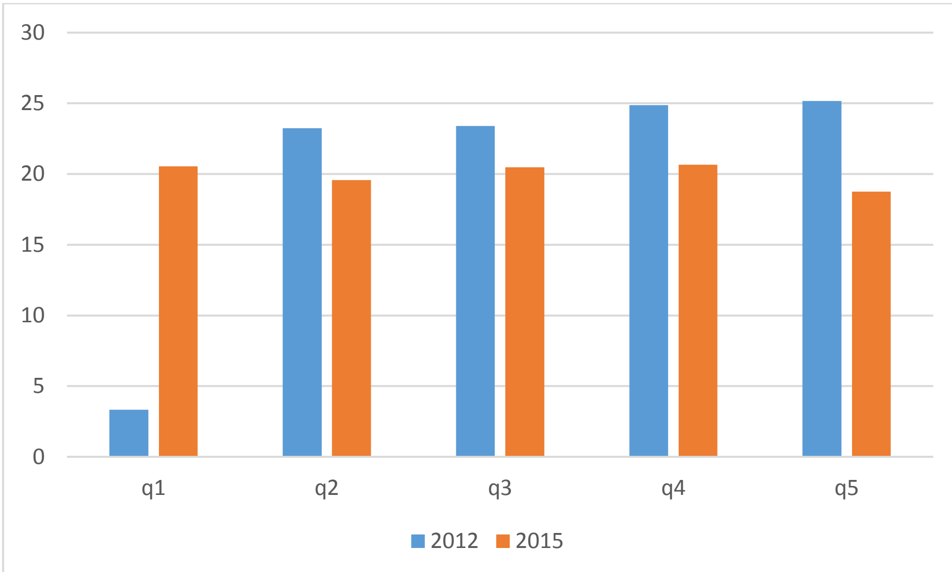

Figure 4.5: Benefit Incidence for Electricity Subsidy 2012 and 2015.

However in 2015, after controlling for inflation, the cumulative impact of the three major changes in the tariff structure (2013) had a sizeable impact on the benefit incidence, which affected the poorest 20% of the population the most. According to our estimates the share of benefits to the poorest 20% of population was 3.3% of the total subsidy in 2012 which increased to 21% in 2015. This increase in the benefit to the poorest 20% of the HHs has reduced the benefits to the HHs in the higher income quintiles, with a reduction of 3-5% in the share of subsidies for each group. For example, the benefit incidence for the HHs in second income quintile (q2) was 23% in 2012 which has reduced to 20% in 2015. Similarly for HHs falling in the third income quintile (q3) it has reduced from 23% to 20% while for fourth income quintile it has reduced from 25% to 21% and for fifth quintile it has reduced from 25% to 19%. The detailed table for each slab is given in the appendix (Table A8).

Comparing these results with the benefit incidence analysis of Trimble et al., 2011, these results show that the electricity incremental block tariff (IBT) structure has improved significantly after the 2013 policy reform. Although this has given some degree of protection for the poor HHs but the richest 40% of the HHs are still receiving 40% of the total electricity subsidies which is same as that received by the poorest 40%. The share of subsidy of the richest 40% HHs has declined to 39% (which was 48% in 2012) but still there is significant leakage of resources to the richest HHs that do not require the same degree of protection as the poor. This means that even by increasing the tariff rates for the higher slabs and keeping the rate same for the lower slabs, the poor are still getting limited benefit.

There are several reasons why the benefit incidence is limited for the poor. Firstly, lifeline remains to be ineffective. Since the minimum charge set for electricity usage is Rs.75, a household consuming 10 kWh/ month is expected to be charged Rs.20 but end up being charged Rs. 75 because of the minimum charge rule. Using June 2015 tariff, it is only at consumption of 38 kWh when the charge becomes greater than Rs.75, which means that only those HHs will benefit from the lifeline tariff that consume between 38-50kWh.

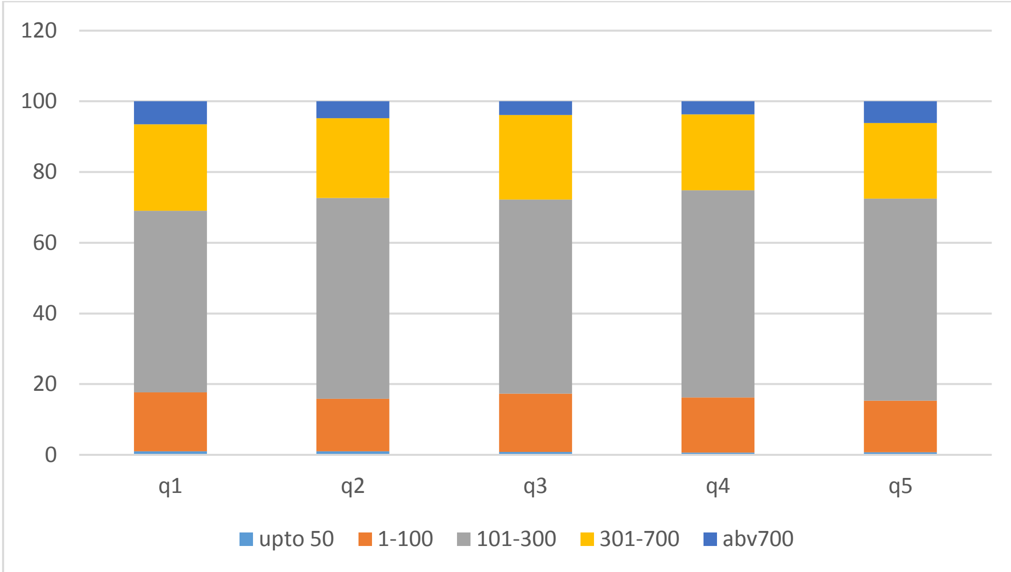

Figure 4.6: Electricity Consumption by quintiles, 2012.

Another reason is the consumption behavior of poor HHs does not match the tariff structure. As it can be seen in Fig 5.6 that only 1% of the poorest HHs consume less than 50kWh/ month in both of the years. While 50% of the poorest HHs consume between 101-300kWh/month in 2012 which has increased to 60% in 2015. This shows that having a lifeline tariff for less than 50kWh consumption is not an effective method to give protection to the poor.

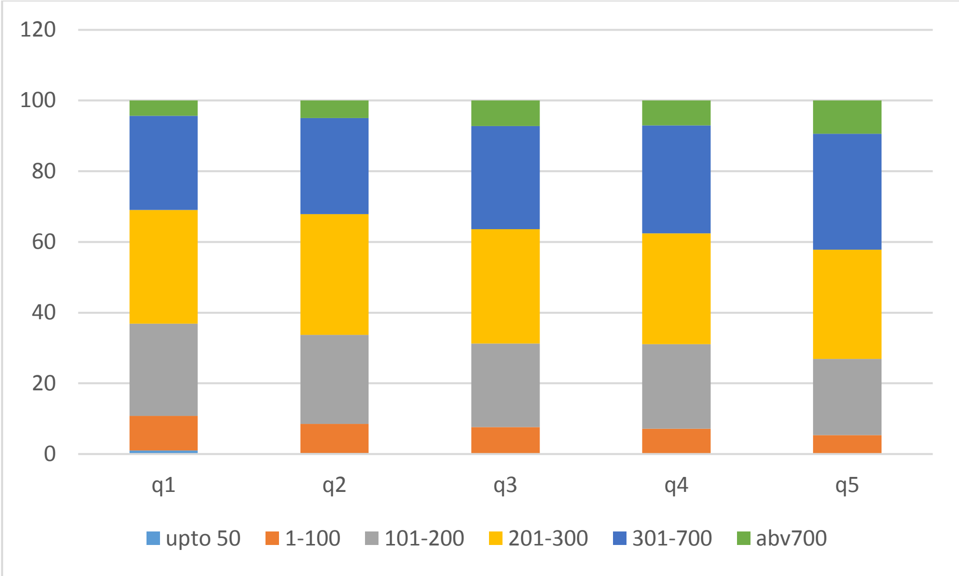

Figure 4.7: Electricity Consumption by quintiles, 2015

One more reason is that the slab benefit structure is for all of the HHs, which means that the rich HHs receive the same level of subsidies as the poor HHs for the first 300kWh of electricity consumption. As long as the tariff rate for electricity units below 300kWh remains less than the cost of supply, there will be a significant leakage of subsidies towards the rich HHs. In order to remove such inefficiencies a pricing policy that targets the subsidy level will be beneficial. In this regard the impact of three pricing policies is explored: (1) increasing the tariff for all the slabs by 20%. In this case the subsidies received by HHs under all slabs will decline. (2) Increasing the tariffs by 20% for only the slabs above 100kWh. In this case the users consuming electricity below 50kWh and between 1-100kWh will not be effected. While the subsidies of users falling under the higher slabs will be reduced. (3) Increasing the tariffs by 20% for only the slabs above 200kWh.

Table 4.7: Effects of policy reform on subsidy and quantity consumed of electricity

Income Group	No of HHs	Reduction in Consumption (kWH)	Decline in welfare (% of total)	Reduction In Subsidy Received (Rs.)	Decline in the Benefit (%)
a. 20% increase in tariff for all slabs					
Q1	3642	38874.76	18.84	2553325	20.17
Q2	3636	38584.43	18.70	2467275	19.49
Q3	3701	43296.99	20.99	2617194	20.67
Q4	3600	44062.3	21.36	2629291	20.77
Q5	3680	41495.93	20.11	2392710	18.90
Total	18259	206314.4		12659795	
b. 20% increase in tariff of slabs whose consumption volume is greater than 100kwh					
Q1	3642	34667.3	18.23	2174724	19.36
Q2	3636	35294.46	18.56	2178955	19.40
Q3	3701	39996.7	21.04	2327923	20.72
Q4	3600	40890.04	21.51	2352761	20.95
Q5	3680	39286.51	20.66	2198443	19.57
Total	18259	190135		11232806	
c. 20% increase in tariff of slabs whose consumption volume is greater than 200kwh					
Q1	3642	24540.16	17.33	1343892.95	18.29
Q2	3636	25567.58	18.06	1378892.96	18.76
Q3	3701	29762.31	21.02	1499607.65	20.41
Q4	3600	30379.97	21.46	1531462.85	20.84
Q5	3680	31327.41	22.13	1594416.9	21.70
Total	18259	141577.4		7348273	

In this case the users consuming electricity below 50kWh, between 1-100kWh and between 101-200kWh will not be effected. While the subsidies of users falling under the higher slabs will be reduced. The impact on the quantity consumed (a measure of welfare) by each quintile and the subsidy received is calculated by the constant elasticity inverse demand function using household data for the year 2015[19]. The results are given in Table 4.7.

These results show that the impact of increasing tariffs on all of the slabs by 20% (given in panel "a" of table 4.7) reduces the subsidy benefit for the poorest 20% more than the richest 20%. As increasing the tariff on all the slabs would raise the price of electricity for all of the slabs reducing the benefit received by HHs of all income groups. The benefit of subsidy received by the poorest quintile reduces by 24% while for the richest income group it reduces by only 16% (shown in Figure 4.8).

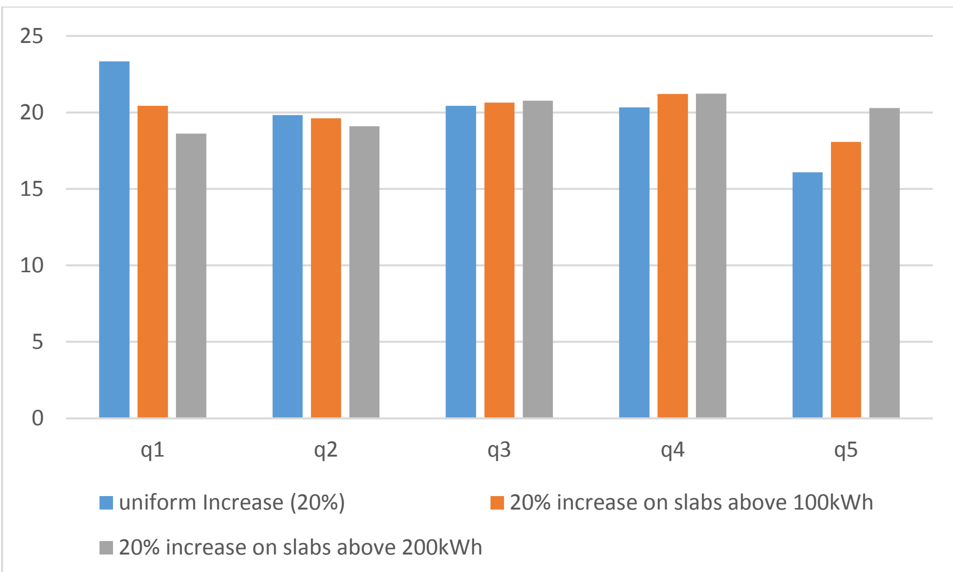

Figure 4.8: Reduction in Benefit incidence under uniform and non-uniform tariff increase

[19] The detailed table of the impact in quantity consume is given in the appendix (table A7).

Under the second policy reform i.e. by raising tariffs for slabs that are greater than 100kWh (given in panel "b" of Table 4.7) the share of subsidy loss by the poorest 20% has declined (reduced from 23% to 20%) while it has increased for the rest of the HHs in higher income quintiles, yet the difference between the richest 20% and the poorest 20% is very nominal. As 89% of HHs in lowest income quintile consume more than 100kWh/month, such a tariff policy will reduce the welfare of the poor HHs by increasing the cost of electricity for majority of the HHs in the poorest income group. Therefore such an increase in tariff would be ineffective in targeting the poor[20].

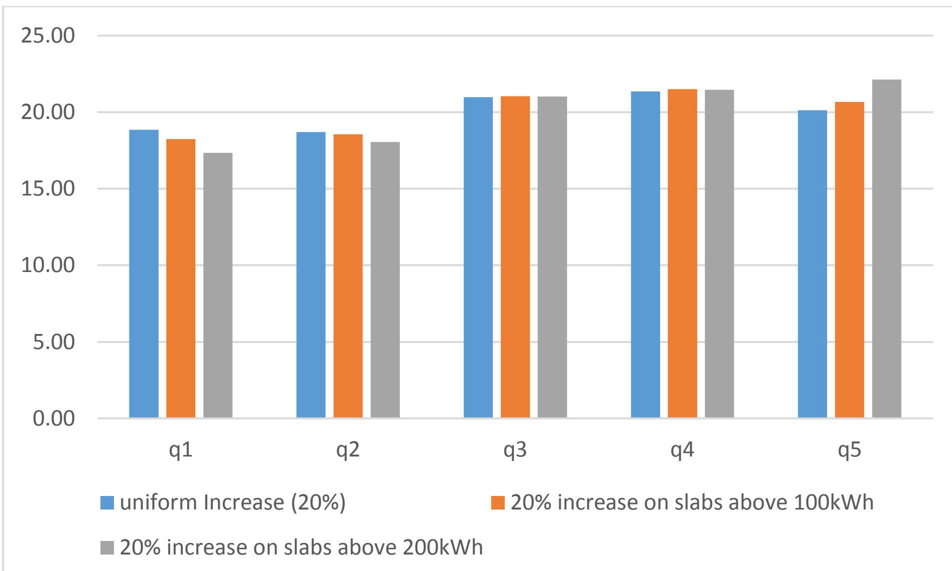

Figure 4.9: Reduction in electricity consumption (welfare) due to increase in Tariffs

Under the third policy reform i.e. increasing the tariff rate for the slabs above 200kWh (given in panel "c" of Table 4.7) not only reduces the share of subsidy loss (18%) for the poorest 40% of HHs but also the welfare loss is the greatest for the richest 20%. About 75% of the richest HHs consume more than 200kWh/month therefore such a policy reform would affect majority of the HHs in the richest income group bringing a decline in

[20] A detailed table estimated for each slab is provided in the appendix (A7).

the subsidy received by 20%. These results show that a targeted tariff structure proves to be more effective in providing protection to the poor than a uniform increase in tariff across all of the slabs.

4.8 Conclusion and Policy Implications

Although electricity subsidies are provided as a source of protection and social safety net for the poor, the analysis of tariff structure and household expenditure data in this chapter demonstrates that residential electricity subsidies are still regressively targeted. Many poor HHs are still exposed to high cost of electricity. Considering the power policy reform 2013 this study estimates the scale of electricity subsidies received by 4 main sectors i.e. Residential, Commercial, Industry and Agriculture. It has been observed that although the tariffs have been increased as a result of the policy reform, the residential sector is still significantly subsidized at the cost of higher tariffs for the commercial and industrial sector increasing the inefficient use of electricity. The impact of phasing out subsidies has also been analyzed which shows that potential energy can be saved by charging tariffs equal to the supply cost of electricity in case of the residential sector. However, the commercial and industrial sector are not getting any subsidies which reduces their productivity. By charging a price equal to the average cost of supply their productivity can be increased boosting the economic activity.

The benefit incidence analysis reveals that the power policy reform (2013) has improved the IBT structure significantly. It has reduced the cost of electricity for consumers using up to 200kWh/month which amounts to 32% of HHs, increasing the subsidies received by the poorest 20% by 18%. The results show that the subsidies received by the higher income groups have not reduced substantially and there is still significant leakage of resources to the richest HHs. These results suggest that by a nominal increase in the tariff rates for the higher slabs (above 200kWh) and no change in the highest slab (above 700 kWh), the poor are still getting a limited benefit from the electricity subsidies. These results also suggest that that the minimum charge of Rs.75 proves to be inefficient. The minimum charge is set to recover the cost of customer service. The cause of providing a lifeline tariff to the poor becomes redundant due to the minimum charge as it increases the cost of electricity. In order to protect the poor by giving a life line tariff this minimum charge should be removed. Moreover to improve the targeting of the lifeline tariff, it should be associated with the consumption patterns. As it is seen that only 1% of the poorest HHs consume up to 50kWh/month. By extending the lifeline tariff to a higher slab i.e. 100 kWh/month accompanied by higher tariff rates for the remaining slabs. However such a change in policy will require further analysis of electricity consumption by poor HHs to understand if setting 100kWh as threshold is effective or not.

In order to evaluate how a more aggressive increase in the tariff rates would help in bringing significant gains for the poor a comparison has been made among 3 scenarios i.e. a uniform increase of 20% across all slabs a non-uniform increase of 20% only for slabs greater than 100kWh and a non-uniform increase of 20% only for slabs greater than 200kWh. The results of this scenario analysis show that targeting higher slabs with no change in the tariff for lower slabs proves to be more effective in providing protection to the poor. By increasing the cost of electricity the consumption of electricity can be reduced through price signals among the richer HHs that are able to cut their consumption which could in turn reduce the electricity demand as the budget share of electricity is higher in case of rich HHs as compared to the poor (details can be seen in chapter 3).

However, it has been observed that even if the tariffs are increased for the higher volume slabs, still the improvement in the benefit incidence is limited for the poor. The richest 40% of the HHs who do not require any support through subsidy will still receive around 40% of the total electricity subsidies. In such a situation the benefit incidence can be improved by charging higher tariff rates for consumers having a high consumption of electricity. For example, the tariff structure can be revised for consumers using more than 300kWh by raising the tariffs for 100-200 kWh and 201-300kWh slabs to the cost of supply. This will reduce the leakage to the rich and it will be possible to improve the benefit incidence for the poor who will suffer if the price of electricity is raised uniformly for all the users.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This dissertation provides a comprehensive analysis of the demand structure of energy in Pakistan by conducting three empirical investigations using macro (sectoral data) and micro (household data) level data. In particular it explores the responsiveness of energy demand to price changes, the possibilities of inter factor and inter fuels substitution and the welfare impact of price reform of electricity. In the first essay the demand functions of energy sources (Electricity, natural gas and petroleum products) by different economic groups (i.e., households, industry, commercial and agricultural sectors) over a period of 35 years (1984-2019) have been analyzed. To examine the relationship between energy consumption and its determinants (energy prices, GDP, number of users, institutional quality etc.), this study has employed bound testing approach to cointegration (ARDL approach) developed by Pesaran et al. (2001). In this study, we make an effort to fill the gap of the shortcomings in the existing literature to provide reliable evidence and recommendations to the policy makers. The results reveal that energy demand is positively related to the income and the number of consumers for all the sectors of the economy. While, the own price exerts negative impact on the energy demand with expected signs. The short run elasticities are much lower than the long run estimates which suggests that the demand management policies will have a stronger effect over time. However, the magnitude of the price elasticities is quite small while, the income elasticities are found to be insignificant in most of the cases. The institutional quality index has been found significant for all the sectors indicating the importance of government provision of energy goods in energy consumption.

The second objective of this essay was to examine the possibility of substitution between energy(electricity, natural gas and petroleum products) and non-energy (capital and labor) input factors in order to cope with supply shortfalls and give policy recommendations for energy security. Considering how the rise in international oil prices has made the energy production so costly specifically the thermal generation of power using expensive imported furnace oil in the recent years, this essay tries to suggest possible technological approaches to meet the energy requirements by examining the extent of inter-fuel and inter-factor substitution. Earlier studies have not addressed the possibility of inter fuel substitution. Considering the widening supply demand gap and high degree of vulnerability to oil price shocks it is much needed to investigate the potential of inter fuel substitution among various energy sources. For this purpose a trans-log production function has been used for the estimation of substitution elasticities between capital, labor, electricity, petroleum and gas after estimating their output elasticities covering the period 1980-2019. The ridge regression methodology has been applied due to the problem of multicollinearity present in the data. The positive output elasticities indicates that all the factors contribute towards economic growth. Moreover, positive substitutability enhances the need of increased investment in efficient energy saving technologies. Moreover, the results also suggests substitutability between labor and energy items which means improved skills and knowhow would result in energy conservation.

In the second essay we have made an effort to analyze in detail the intertemporal patterns of household expenditure on three main energy sources i.e. electricity, natural gas and petrol and diesel using Pakistan Social and Living Standards Measurement Survey (PSLM) data for the years 2005-06, 2010-11 and 2015-16 for urban and rural HHs. Further the price and income elasticities are computed with the Extended Linear Expenditure System methodology which was also used by Burney and Akhtar (1990). Estimating price and income elasticities over three different periods of high (2005-06), low (2010-11) followed by fluctuating oil price (2015-16) reveals how the international oil prices has affected the energy prices and energy consumption of Pakistan. Previous studies on energy demand by the household sector have not analyzed the demand for petrol and diesel along with the other fuels consumed by the HHs. In order to analyze the impact of changing energy prices in response to the international oil price shocks it is necessary to consider the consumption of petrol and diesel by HHs as the petroleum products are directly influenced by such changes. The results show that Quintile wise household per capita expenditure witnessed a rise in electricity natural gas and petrol for both urban and rural HHs during 2006-16, however the growth in per capita expenditure in these energy sources is observed to be higher in case of rural HHs. The marginal budget shares of all the three sources have been found to be on lower side across the three periods for both urban and rural HHs. The marginal budget shares of the urban HHs are seen to be relatively higher than the urban counterparts. The income elasticities of all the three sources are found to be less than unity, indicating that all the three sources behave as normal goods. The price elasticities are found to have the expected negative signs with low magnitudes indicating they are less responsive to changes in price.

In the last essay we have made an effort to analyze how well the poor are targeted through electricity subsidies and to quantify the size of electricity subsidy for each sector and assess the potential impact of subsidy removal on electricity consumption by each sector (residential, commercial, industry and agriculture) before and after the policy reform

2013. In case of Pakistan the impact of subsidy has been analyzed only for the domestic sector. This study not only computes the quantity of subsidy given to each sector it also analyzes the extent of cross subsidization present among these sectors. Furthermore, it provides a benefit incidence analysis to compare the amount of subsidies different income group receive before and after the 2013 policy reform. Following Trimble et al., (2011), the benefit incidence analysis is carried out for the year 2012 and 2015 in order to determine how successful the policy reform has been in targeting the poor HHs. Further we analyzed the impact of a uniform and non-uniform policy changes in order to understand the effectiveness of such policy reforms for providing protection to the poor. The results show that although electricity subsidies are provided as a source of protection and social safety net for the poor, the analysis of tariff structure and household expenditure data in this chapter demonstrates that residential electricity subsidies are still regressively targeted. It has been observed that although the tariffs have been increased as a result of the policy reform, the residential sector is still significantly subsidized at the cost of higher tariffs for the commercial and industrial sector increasing the inefficient use of electricity. The impact of phasing out subsidies shows that potential energy can be saved by charging tariffs equal to the supply cost of electricity in case of the residential sector.

The commercial and industrial sector are not getting any subsidies which reduces their productivity. By charging a price at least equal to the average cost of supply their productivity can be increased boosting the economic activity. The benefit incidence analysis reveals that the power policy reform (2013) has improved the IBT structure significantly. It has reduced the cost of electricity for consumers using up to 200kWh/month increasing the subsidies received by the poorest 20%. The results show that the subsidies received by the higher income groups have not reduced substantially and there is still significant leakage of resources to the richest HHs. The results of the uniform and non-uniform tariff increase shows that even if the tariffs are increased for the higher volume slabs, still the improvement in the benefit incidence is limited for the poor. The richest 40% of the HHs who do not require any support through subsidy will still receive around 40% of the total electricity subsidies.

5.2 Recommendations

Following recommendations can be put forward on the basis of empirical results obtained in this study. Firstly increasing the prices of energy alone may not be affective for energy conservation purposes as the magnitude of the price elasticities is small for all the sectors of the economy. The government must also provide alternative energy saving appliances along with a focus upon the population growth rate in the country. It should formulate such policies that could reduce the population growth rate. Moreover, the results also indicate that the energy sector reforms should also pay attention towards institutional constraints in addition to capacity building efforts. Although, village electrification and natural gas provision programs which require large scale infrastructure have been carried out by the state, there is now a need to focus on decentralized development plans. Such small scale decentralized generation and distribution efforts will require a lower cost as compared to the expansion of the grid at national level. The positive substitution elasticity of capital and energy sources suggests that there is possibility of energy conservation with an increased use of energy saving technology in addition to the removal of energy subsidies. True energy prices will encourage the use of capital intensive methods in order to save more energy. The positive substitution elasticity of oil by gas in Pakistan implies that Pakistan can shift its load of power generation from costly oil to natural gas as there is positive elasticity of substitution between them which will reduce the heavy import bill.

Furthermore, it is apparent from the second essay that if the government reduces subsidy on different fuels, their prices will go up by definition but their demand may not decline appreciably. As the price elasticities are found to be very low, household will continue to demand according to their needs. Moreover, it has been observed that although the tariffs have been increased as a result of the policy reform 2013, the residential sector is still significantly subsidized at the cost of higher tariffs for the commercial and industrial sector increasing the inefficient use of electricity.

The impact of phasing out subsidies shows that potential energy can be saved by charging tariffs equal to the supply cost of electricity in case of the residential sector. However, the commercial and industrial sector are not getting any subsidies which reduces their productivity. By charging a price equal to the average cost of supply their productivity can be increased boosting the economic activity. The government may like to reduce subsidy across the consumption quintiles excepting first and second (the poorest HHs) to improve the country's budgetary situation without adversely affecting the relatively affluent classes. The benefit incidence analysis shows that charging higher price of energy (electricity) for consumers having a high consumption will reduce the leakage to the rich and it will be possible to improve the benefit incidence for the poor who will suffer if the price of electricity is raised uniformly for all the users.

5.3 Limitations of the Study

This scope of this study could be broadened if sufficient data for renewable energy was available. There are no duel costs of renewable energy sources such as Hydel, Solar and

Wind (NEPRA, 2017). China has invested $46 billion in CPEC power projects that focus on renewable energy sources such as solar panel which will decline the use of oil in power production. However, since CPEC was announced in 2015, the time frame of the available data is quite short. Data availability on renewable sources will give a new dimension to the analysis of substitution possibilities. Another constraint that limits the scope of the study is the unavailability of data on the actual electricity units consumed. The units consumed have been computed by dividing the expenditure according to the tariff structure. Households reporting less than 50 Rupees expenditure on electricity usage has to be excluded from the data. Non availability of charges deducted for electricity theft also makes the calculation of exact units consumed overvalued.

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Appendix

Table A1. Ex-depot Sale Price Build up Formula

i	**Ex-refinery Import Price**	**As per refineries pricing formula based on fortnightly international market (Arab gulf) price**
ii	Custom/ excise duty	As per CBR notified rate
iii	Petroleum development levy (PDL)	As per rate notified by the ministry of petroleum and natural resources in consultation with finance division
iv	Distribution margin for Oil marketing companies (OMCs)	Actual transportation cost determined by OMCs
v	Sub total-A	i+ii+iii+iv
vi	Distribution margin for Oil marketing companies (OMCs)	3.5% of (v)
vii	Dealers commission	4.0% of (v)
viii	Price before GST	Sub-total (A)+vi+vii
ix	General sales tax	15 % of price before GST at viii
x	Ex-depot sale price	(viii)+(ix)

Source: Ministry of Petroleum and Natural Resources

Table A2. Covariance Matrix

	gdp	k	l	g	p	e	KL	KP	KG	KE	LG	LP	LE	GP	GE	PE	KK	LL	GG	PP	EE
gdp	1.00	0.97	0.98	0.98	0.92	0.98	0.97	0.99	0.98	1.00	0.99	1.00	1.00	0.98	0.99	0.97	0.96	0.98	0.98	0.92	0.98
k	0.97	1.00	0.99	0.95	0.82	0.90	1.00	0.99	1.00	0.98	0.99	0.98	0.97	0.92	0.93	0.89	1.00	0.99	0.95	0.82	0.92
l	0.98	0.99	1.00	0.90	0.97	0.96	0.97	0.98	0.99	0.98	0.98	0.99	0.98	0.99	0.96	0.94	0.96	1.00	0.90	0.98	0.95
g	0.98	0.95	0.97	1.00	0.97	0.83	0.90	0.84	0.90	0.87	0.91	0.91	0.97	0.94	0.98	0.80	0.84	0.89	1.00	0.96	0.98
p	0.92	0.82	0.86	0.90	1.00	0.91	0.95	0.93	0.97	0.95	0.97	0.98	0.99	1.00	1.00	0.89	0.93	0.97	0.97	1.00	0.96
e	0.98	0.90	0.94	0.97	0.97	1.00	0.99	1.00	0.98	0.99	0.98	0.98	0.92	0.94	0.90	1.00	1.00	0.96	0.83	0.92	1.00
KL	0.97	1.00	1.00	0.96	0.83	0.91	1.00	0.99	1.00	0.99	1.00	0.99	0.97	0.97	0.95	0.98	0.99	0.97	0.90	0.96	0.92
KP	0.99	0.99	0.99	0.97	0.90	0.95	0.99	1.00	0.99	1.00	0.99	0.98	0.94	0.95	0.92	0.99	0.99	0.98	0.85	0.94	0.96
KG	0.98	1.00	0.99	0.98	0.84	0.93	1.00	0.99	1.00	0.99	1.00	1.00	0.98	0.98	0.96	0.98	0.99	0.99	0.91	0.98	0.94
KE	1.00	0.98	0.99	0.99	0.90	0.97	0.98	1.00	0.99	1.00	0.99	0.99	0.96	0.97	0.94	0.98	1.00	0.98	0.87	0.96	0.98
LG	0.99	0.99	1.00	0.98	0.87	0.95	0.99	0.99	1.00	0.99	1.00	1.00	0.98	0.98	0.96	0.97	0.99	0.98	0.92	0.97	0.96
LP	1.00	0.98	0.99	0.98	0.91	0.97	0.98	1.00	0.99	1.00	0.99	1.00	0.98	0.99	0.97	0.97	0.99	0.99	0.91	0.98	0.97
LE	1.00	0.97	0.99	0.99	0.91	0.98	0.98	0.99	0.98	1.00	0.99	1.00	1.00	1.00	1.00	0.91	0.94	0.98	0.97	1.00	0.98
GP	0.98	0.92	0.95	0.98	0.97	0.99	0.92	0.97	0.94	0.98	0.96	0.98	0.98	1.00	0.99	0.92	0.95	0.99	0.95	1.00	1.00
GE	0.99	0.93	0.96	0.99	0.94	1.00	0.94	0.97	0.95	0.98	0.97	0.98	0.99	1.00	1.00	0.88	0.92	0.96	0.98	1.00	1.00
PE	0.97	0.89	0.93	0.96	0.98	1.00	0.90	0.95	0.92	0.96	0.94	0.96	0.97	1.00	0.99	1.00	0.99	0.95	0.81	0.91	1.00

KK	0.96	1.00	0.99	0.94	0.80	0.89	1.00	0.98	0.99	0.98	0.98	0.97	0.97	0.91	0.92	0.88	1.00	0.96	0.84	0.94	0.91
LL	0.98	0.99	1.00	0.96	0.84	0.93	1.00	0.99	0.99	0.99	1.00	0.99	0.99	0.94	0.95	0.92	0.99	1.00	0.89	0.98	0.94
GG	0.98	0.95	0.97	1.00	0.89	0.97	0.96	0.97	0.98	0.99	0.98	0.98	0.99	0.98	0.99	0.96	0.95	0.96	1.00	0.96	0.98
PP	0.92	0.82	0.86	0.90	1.00	0.97	0.83	0.90	0.85	0.91	0.87	0.92	0.91	0.97	0.95	0.98	0.81	0.84	0.89	1.00	0.96
EE	0.98	0.92	0.95	0.98	0.96	1.00	0.92	0.96	0.94	0.98	0.96	0.97	0.98	1.00	1.00	1.00	0.91	0.94	0.98	0.96	1.00

Table A3. Results of ADF Test

ADF		
Variables	Level	1st Diff
GDP	-2.71	-4.09***
EC (AGRI)	-2.97**	-6.65***
EC (COM)	-2.97**	-9.48***
EC (DOM)	-1.42	-5.82***
EC (IND)	-2.23	-5.64***
GC (DOM)	-2.21	-9.35***
GC (COM)	-1.62	-4.41***
GC (IND)	-1.30	-3.31**
FO	-3.13**	
HOBC	-1.12	-3.15**
HSD	-3.01**	
LDO	-2.00	-5.47***
MS	-0.18	-7.281***
SK	0.630	-4.80***
EN (AGR)	-0.51	-5.65***
EN (COM)	0.494	-3.25**
EN (DOM)	-1.77	-5.433**
EN (IND)	-0.99	-5.82***
GN (COM)	-0.48	-3.30**
GN (DOM)	3.159	-3.76***
GN (IND)	-1.93	-3.37**

EP (IND)	0.775	-5.34***
EP (COM)	1.268	-5.13***
EP (DOM)	0.550	-5.47***
EP (IND)	1.243	-4.53***
TC	-1.93	-6.18***
GP (COM)	-0.54	-6.44***
GP (DOM)	1.089	-5.24***
GP (IND)	-1.48	-5.84***
SKP	0.169	-6.43***
HSDP	0.37	-7.13***
FOP	-3.600**	
MSP	-2.34	-4.56***

Table A4 ARDL Stability Tests Result

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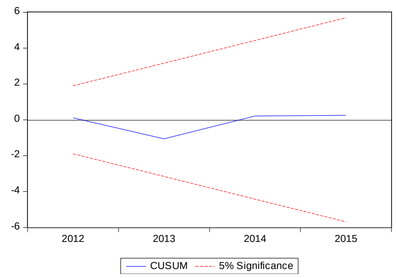
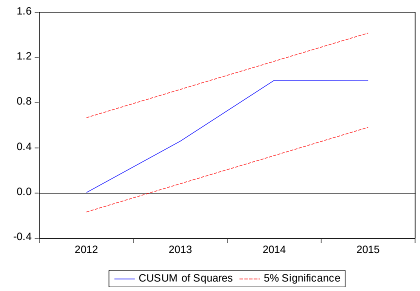
<tr><td>EC(H)</td><td>
</td><td>
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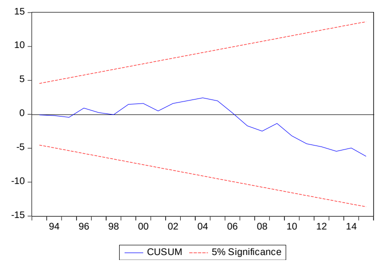
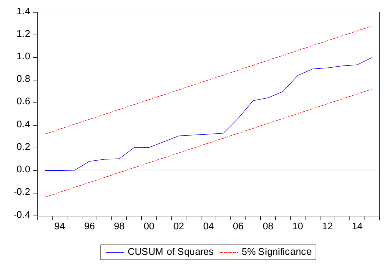
<tr><td>EC(I)</td><td>
</td><td>
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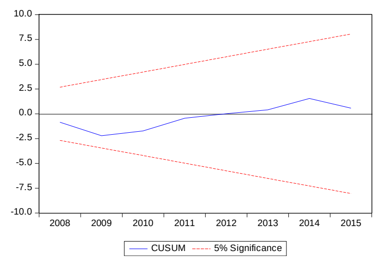
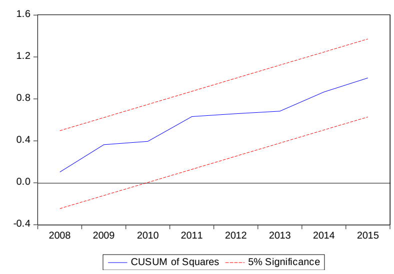
<tr><td>EC(C)</td><td>
</td><td>
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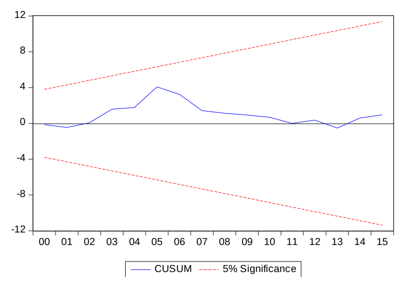
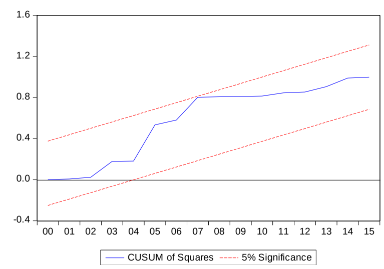
<tr><td>EC(A)</td><td>
</td><td>
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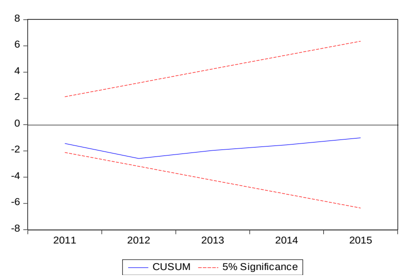
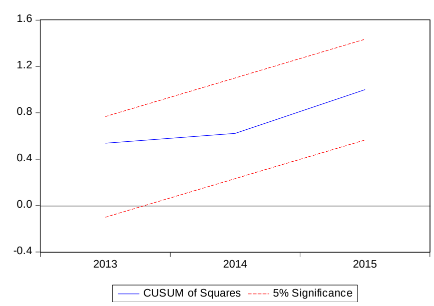
<tr><td>GC(H)</td><td>
</td><td>
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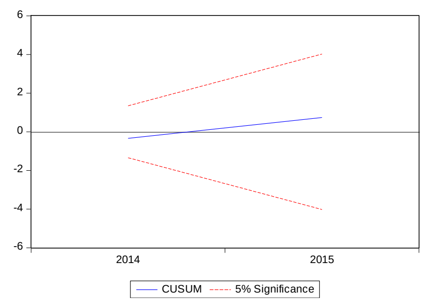

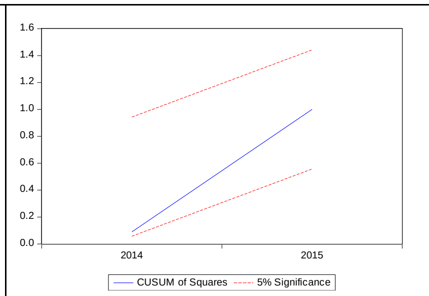

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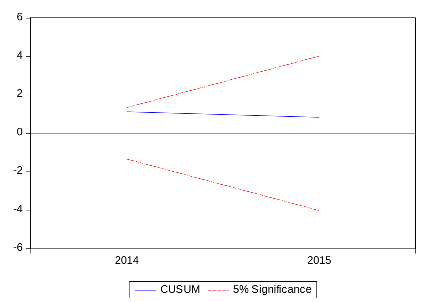

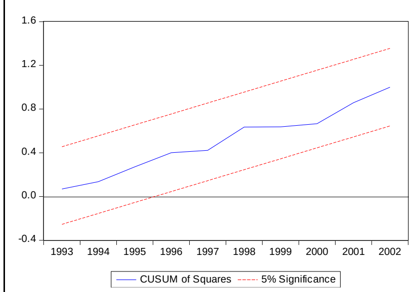

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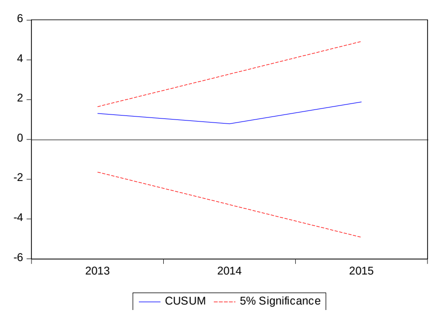

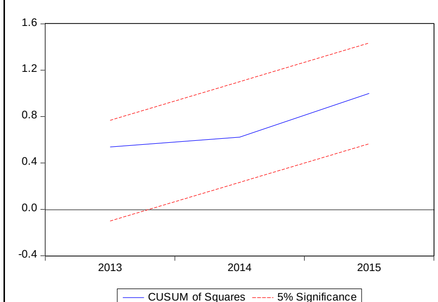

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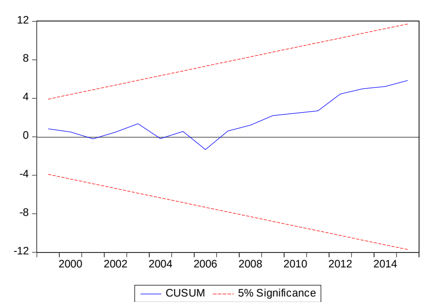

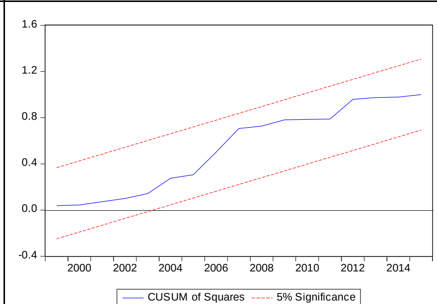

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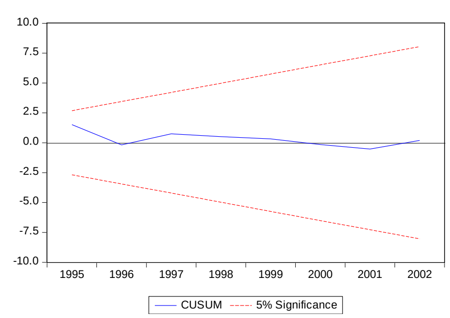
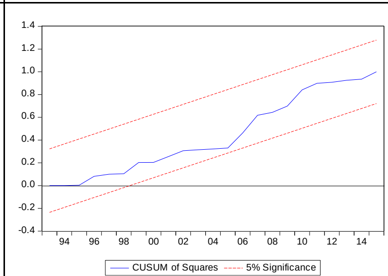




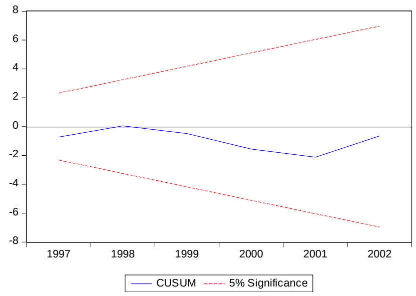
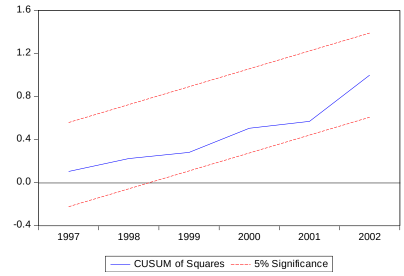
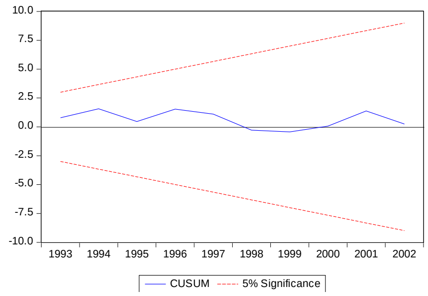
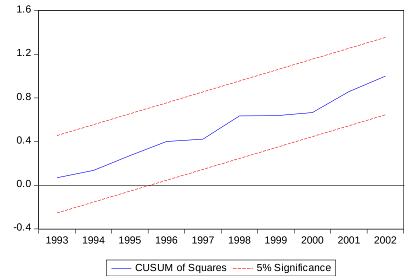
MS	 8 6 4 2 0 -2 -4 -6 -8 1997 1998 1999 2000 2001 2002 CUSUM 5% Significance	 1.6 1.2 0.8 0.4 0.0 -0.4 1997 1998 1999 2000 2001 2002 CUSUM of Squares 5% Significance
LDO	 10.0 7.5 5.0 2.5 0.0 -2.5 -5.0 -7.5 -10.0 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 CUSUM 5% Significance	 1.6 1.2 0.8 0.4 0.0 -0.4 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 CUSUM of Squares 5% Significance

Table A5. Tariff Structure by each Disco

2012	GOP	LESCO	GEPCO	FESCO	IESCO	MEPCO	HESCO	SEPCO	QESCO	PESCO	Average	
Residential	8.66	8.2	11.61	11.52	10.48	12.38	12.8	13.06	11.4	13.33	11.64222	
Commercial	12.24	14.75	16	15.75	13.75	17.25	15.5	15.5	16	18.25	15.86111	
Industry	10.28	10.28	14.11	11.93	11.53	12.75	14.47	14.63	10.17	15.34	12.80111	
Agriculture	7.84	9	10.25	10.25	9.6	11	12.05	12.25	12.25	13.8	11.16111	
2015												
	GOP	LESCO	GEPCO	FESCO	IESCO	MEPCO	HESCO	SEPCO	QESCO	PESCO	TESCO	Average
Residential	10.01	10.59	13.3	10.56	10.33	11.42	12.13	10.58	13.75	14.4	14.9	12.196
Commerce	17	14	17	14.75	13.5	15	14	17	17	17	18	15.725
Industry	14.95	12.04	15.56	12.8	11.94	13.16	12.82	15.56	15.56	15.68	16.26	14.138
Agriculture	11.09	11.75	14.25	12.75	11.75	13.25	12.25	15.25	14.95	14.25	14.75	13.52

Table A6. Supply Cost of Power Stations

Power Station/ Fiscal Year ending 30th June	2012	2015
IPPs		
Lal Pir Power	18.78	14.32
Pak Gen. Power	18.99	19.31
HUBCO	18.66	15.89
Saba Power	25.12	17.63
Japan Power	17.58	0
Southern Power	9.68	0
Kohinoor Energy	16.65	13.36
Attok Gen.	18.14	18.21
Atlas Power	18.24	19.21
Nishat Power	18.91	13.64
Nishat Chunian	18.95	16.81
Liberty Power Tech	14.85	19.32
HUBCO narowal	17.15	16.26
Altern energy	5.54	7.06
Fauji Kabirwala	4.91	5.19
Habibullah Coastal	4.89	13.34
Rousch Power	4.98	5.65
TNB liberty power	7.22	8.09
UCH power	5.07	5.65
Davis Energen	4.86	8.09
KAPCO	15.21	16.39

Sapphire Electric	6.49	19.24
6.49Saif POWER	7.33	21.83
Orient Power	6.22	18.41
Engro Power	4.60	5.37
Foundation Power	4.43	7.71
Halmore Power	8.45	13.98
Uch Power II	6.18	1.94
GENCO-1		
TPS Jamshoro	23.05	9.25
GTPS Kotri	7.86	8.25
GENCO-2		
TPS Guddu (1-4)		8.16
TPS Guddu (5-13)	6.18	5.78
Guddu G.T.P.S		
TPS Quetta	9.00	11.7
GENCO-3		
TPS Muzaffargarh	19.39	8.89
SPS Faisalabad	4.17	9.05
GTPS Faisalabad	97.81	8.18
NGPS Multan	28.09	
GTPS Shahdara	0.00	
Nandipur		7.65
GENCO-4		
Lakhra F.B.C	10.56	11.72

Table A7 Impact of Phasing out subsidies on Sectors

2012							
Sector	Reference Price	Consumer Price	Subsidy	Initial Consumption	Final Consumption	Initial Subsidy	Final Subsidy
Residential	9.47	8.66	0.81	35589000000	34307939018	28827090000	27789430605
Commercial	9.47	12.24	-2.77	5754000000	5843267170	-ve subsidy	-ve subsidy
Industry	9.47	10.28	-0.81	21801000000	22089165882	-ve subsidy	-ve subsidy
Agriculture	9.47	7.84	1.63	8548000000	7432919262	13933240000	12115658397
2015							
Residential	12.00	10.01	1.99	4.37E+10	40587641356	87002800000.00	80769406298
Commercial	12.00	17.00	-5.00	7.1E+09	7251982184	-ve subsidy	-ve subsidy
Industry	12.00	14.95	-2.95	2.5E+10	25874146065	-ve subsidy	-ve subsidy
Agriculture	12.00	11.09	0.91	8.53E+09	8042675573	7758660000.00	7318834771

A6. Benefit Incidence (subsidy received by each slab)

2012					
	up to 50	1-100	101-300	301-700	above 700
Q1	22223.25	10034.51	48064.81	63698.31	-46940.8

Q2	23194.35	167267.3	473791		56875.11	-42972
Q3	19978.52	194373.9	482897.6		68346.78	-30891.5
Q4	15694.47	176462.7	494058.4		69310.08	-29164.2
Q5	16777.62	164147.3	483862.3		58544.3	-40418
2015						
	up to 50	1-100	101-200	201-300	301-700	above 700
Q1	57724.6	343938.8	853799	899367.4	444525.5	-28045
Q2	13830.6	288381.2	822123	947867.5	431025.4	-54271.7
Q3	13459.4	289540.2	851527.2	1003237	496371.1	-92834.3
Q4	8314.1	281183.3	845134.6	994293.4	537169.5	-80696.7
Q5	8398	194212.4	754345.7	922873.2	541543.7	-75352.4

Table A8. Impact of 20% increase in Tariff rates

Q1						
	upto 50	1-100	101-200	201-300	301-700	above 700
Initial Consumption	5772.46	55384.66	147202	181871	150574	24256
Final Consumption	5375.329	51574.33	137074.9	169358.7	140214.9	22587.25
Decrease in Subsidy	3812.46	19249.79	22968.35271	negative subsidy	negative subsidy	negative subsidy
Q2						
Initial Consumption	1383	46438	141384	191484	152156	27995

Final Consumption	1287.853	43243.18	131657.1	178310.4	141688	26069.01
Decrease in Subsidy	913.4116	16140.24	22060.55339	negative subsidy	negative subsidy	negative subsidy
Q2						
Initial Consumption	1346	46625	148761	203826	183620	45161
Final Consumption	1253.398	43417.31	138526.6	189803.3	170987.4	42054.03
Decrease in Subsidy	888.9747	16205.23	23211.60798	negative subsidy	negative subsidy	negative subsidy
Q4						
Initial Consumption	831	45279	152768	201024	195528	45033
Final Consumption	782.955	42163.91	142257.9	187194	182076.1	41934.84
Decrease in Subsidy	548.8395	15737.41	23836.83175	negative subsidy	negative subsidy	negative subsidy
Q5						
Initial Consumption	840.8	31274	130224	186624	197422	56775
Final Consumption	773.8292	29122.42	121264.9	173784.7	183839.8	52869.02
Decrease in Subsidy	555.312	10869.76	20319.22639	negative subsidy	negative subsidy	negative subsidy