FORECASTING THE DEMAND OF CRUDE OIL, COAL AND NATURAL GAS IN THE ENERGY SECTOR OF PAKISTAN

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CERTIFICATE

This is to certify that this thesis entitled **"Forecasting the Demand of Crude Oil, Coal and Natural gas in the Energy Sector of Pakistan"** submitted by **Mr. Hassan Ahmad Nizam** is accepted in its present form by the School of Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in Master of Philosophy in Econometrics.

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Author's Declaration

I **Hassan Ahmad Nizam** hereby state that my MPhil thesis titled **Forecasting the Demand of Crude Oil, Coal and Natural Gas in Energy Sector of Pakistan** is my own work and has not been submitted previously by me for taking any degree from Pakistan Institute of Development Economics or anywhere else in the country/world.

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Date: 24/5/2023

Signature of Student
Hassan Ahmad Nizam

Dedicated

To My

Late Father

ACKNOWLEDGEMENT

I am deeply thankful to Almighty Allah, who is Merciful and Graceful, who bestowed me with courage and knowledge to complete this study. All the respect to the Holy Prophet (P.B.U.H), who enables me to recognize our creator and directed me to the righteous path.

I acknowledge and appreciate the scholarly guidance, valuable suggestions and kind advice given by my thesis supervisor Dr. Saud Ahmed Khan under whose supervision this study has been completed.

I cannot express my feelings and thankfulness for my father (late) who always appreciated me, supported me and always encouraged me to continue the hard work. He was the beacon house for me who always showed me the right and bright path. I am also very grateful to my mother for her love, care and prayers.

Hassan Ahmad Nizam

ABSTRACT

Fossil Fuel related Energy Demand is continuously rising day by day and the reserves of these natural resources are limited so to know the future consumption of these fossil fuels are very important. This study’s aim is to make future projections for the demand of Oil, Coal and Natural Gas in Energy sector using ARFIMA with breaks model for next 9 years. Data is taken from 1981-2021 and Projection period is from 2022-2030. Three different empirical models of Oil, Coal and Natural Gas are estimated. Unit Root test with break is used to check the stationarity, two indicator saturation techniques are used for checking breaks in the data after that empirical models are estimated, and ARFIMA-B modeling is used to make projections for Fossil fuels. The projections show the increasing demand of oil till 2030 with cyclic rate, Gas demand will increase after 2022 till 2030 and Coal demand will increase until 2027. This study gives valuable suggestions for the government to make policies which can help in cheaper energy production and to use alternative sources as a main source rather than Fossil Fuel.

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LIST OF ABBREVIATIONS

OLS	Ordinary Least squares
ARIMA	Auto-Regressive Integrated Moving Average
ADF	Augment Dickey Fuller
RET	Renewable Energy Technologies
ECT	Error Correction Term
ECM	Error Correction Model
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
HDIP	Hydrocarbon Institute of Pakistan
TOE	Ton of Oil Equivalent
LEAP	Long-range Energy Alternatives Planning System
SAA	Simulated Annealing Algorithm
TWh	Tetra-Watt hour
Mt	Million Tones
LMDI	Logarithmic Mean Divisia Index
ARDL	Auto-Regressive Distributed Lag Model
RMSE	Root Mean Square Error
SSE	Sum of Square of Error
GHG	Green House Gases
VAR	Vector Auto-Regressive
LCU	Local Currency Unit

CHAPTER 1

INTRODUCTION

1.1 Introduction

For any country, the development of every sector depends on the energy available in the country, whether it would be manufacturing sector, transport sector, services sector or energy sector etc. With the limited resources in the world, global economics are shifting towards renewable energy sources as fossil fuel consumption is depleting the natural resources and environmental hazards do exist with them. There are various energy resources present on our planet, however, the most widely used and recognized one is crude oil, also known as fossil fuel oil. This resource is utilized in multiple forms such as diesel, petrol, kerosene, high octane, jet fuel, etc. Therefore, the consumption, price, and availability of crude oil is a crucial economic matter as it has a significant impact on the growth and development of a country. Petroleum products are used in the transportation, industry, electricity production, and agriculture sectors. (Zaman, 2013; Asif et al.2017). In case of Pakistan, the country is still very much dependent on fossil fuel for fulfilling energy requirements which means that resources are diminishing day by day, and we do not have current infrastructure or resources to shift to renewable energy sources. As major fossil fuels are being imported for energy production, Pakistan must pay millions of dollars for importing crude oil which burdened our already stricken economy. The country is also facing major Power crisis in Urban and Rural Areas and industries do not get required amount of energy to produce goods which is producing bad results for economy. Studies found that Fossil fuel energy consumption has positive and significant relationship with the economic growth of the country (Rehman et al.2022), (Khan et al.2020). The share of Crude oil, Coal and natural gas in the power generation of Pakistan in

2019-20 was 73.9 % only, other sources i.e., LNG, LPG and Electricity contributed 26.1%. This shows that major source of energy for Pakistan is still Fossil fuel. The reserves of these natural resources are limited so shifting to renewable energy sources in the future is becoming more important day by day (HDIP energy year report,2020). So, it is important to estimate how much Oil, Coal and Gas would be needed in coming nine years to produce energy. The purpose of the research topic is to analyze the determinants of Oil, Gas and Coal consumption in the country and made projections about the demand of Fossil Fuel I.e. Crude Oil, Coal and Natural Gas for Energy Sector in upcoming nine years for Pakistan using Engle Granger co-integration technique for analyzing determinants and suitable Econometric Technique such as ARIMAX, ARFIMAX, ARFIMA with breaks included for projections and also to find out the different factors that affects the demand of Oil, Coal and Gas in Pakistan.

1.2 Energy Dynamics of Pakistan

Pakistan is grappling with a severe energy crisis, evidenced by the widening electricity shortfall of 7,000 megawatts. This deepening energy crisis is further exacerbated by the scorching weather conditions, which have escalated the demand for electricity to 28,200 megawatts, while the power supply stands at 21,200 megawatts. Presently, hydropower contributes 4,635 megawatts to electricity generation, with the government's thermal power plants supplying 1,060 megawatts, and independent power producers (IPPs) contributing 9,677 megawatts. The scarcity of oil, gas, and coal has forced the closure of several power plants, intensifying the shortage. Consequently, numerous parts of the country are subjected to prolonged load shedding periods ranging from 10 to 12 hours, greatly impacting the lives of people and causing significant hardships.

The energy crisis in Pakistan has also been aggravated by the government's inability to gather sufficient funds for initiating new power projects. The economic condition of a country plays a vital role in attracting both domestic and foreign funding. Unfortunately, Pakistan's current economic situation does not meet the necessary standards to attract substantial foreign funding. The collection of funds is linked to the budget deficit. As per the Economic Survey of Pakistan, the fiscal deficit of Pakistan reached Rs. 1.13 trillion in 2021. This substantial fiscal deficit poses a significant challenge in initiating new power projects, as it necessitates the availability of specified funds to support such ventures. One of the longstanding issues is the problem of circular debt. Despite the efforts made by successive governments to tackle this issue, circular debt has remained largely uncontrolled. In FY2013, the circular debt was approximately Rs 450 billion, which surged to Rs 1,148 billion in 2018. According to data from the Central Power Purchasing Authority (CPPA), the circular debt had further escalated to Rs 2,467 billion by March 2022. This staggering amount of circular debt represents 3.8 percent of Pakistan's GDP and constitutes 5.6 percent of the government debt.(Energy, PES 2021-22)

In addition to the aforementioned factors, one of the significant causes contributing to the energy crisis in Pakistan is the rampant theft of energy. Unfortunately, this practice has become ingrained within society, with little consideration for the consequences that the country will ultimately face. Shockingly, an estimated 4,500 megawatts of energy is stolen every year, accompanied by the non-payment of approximately 100 billion bills. This widespread energy theft has severe implications for the country's economy. When energy is stolen and bills remain unpaid, it hampers the ability of the country to purchase energy, exacerbating the issue of circular debt that continues to escalate with each passing day. In the year 2021 alone, the recorded amount of energy theft reached a staggering 2.73 trillion. The consequences of such widespread energy theft are detrimental to the overall energy landscape and the economy. It puts an immense burden on the power sector, reduces the revenue stream, and limits the capacity to invest in infrastructure and new energy projects. Addressing and curbing this energy theft is crucial for ensuring a stable and sustainable energy supply in Pakistan. (Irfan et al.2020)

Table 1.1: Fossil fuel consumption in thermal power generation (Ton of oil Equivalent) (HDIP,2020)

Source	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Oil	8,800,431	7,583,155	8,328,980	511,287	2,688,911	1,487,578
Gas	6,847,894	8,577,146	8,643,403	10,831,662	10,050,101	8,426,767
Coal	67,638	91,463	384,585	1,984,722	2,640,347	4,875,302

In fig 1.1, we can see that Gas shows an increasing trend in consumption till 2017-18 for thermal energy production after that the consumption declines, coal shows an increasing trend whereas Oil shows downward trend with passing years

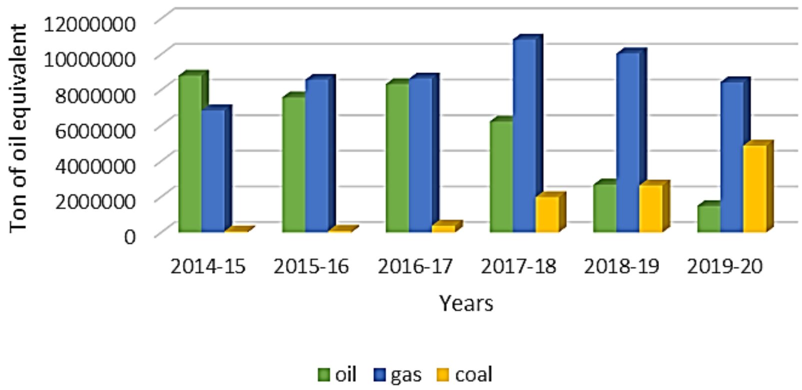

Fig. 1.1**:** Fossil Fuel Consumption in Thermal Power Generation 2015-2020 (HDIP,2020)

The statistics in Table 1.1 itself shows that until 2020, fossil fuel consumption is quite high for producing energy which raises the question about the future consumption of these fuels in the country. This question became the main motivation for the study.

1.3 Statement of the Problem

The study is primary focusing on the Crude Oil, Coal, and Natural Gas demand in energy sector for Pakistan in upcoming years i.e.,2030 by using ARFIMA-B methodology with the inclusion of structural breaks. The main source for Energy Production in Pakistan is still Fossil Fuel and it seems highly unlikely that the fossil fuel share in overall energy mix will going to decrease in future. So, it is particularly important to find out the future consumption of these fuels in the upcoming five to ten years so that we can make policies which would help the country in achieving sustainable energy goals. The fossil fuel demand forecasting also helps the government to make decisions related to future production, supply, and imports etc. which could stop the future energy crisis in the country. As reserves are limited and in 2019-20, the reserves of Oil are recorded as 271 million barrels, 7,775.5 million tonnes of Coal and 20.9 trillion cubic feet of Natural Gas in Pakistan and the consumption rate in Energy sector is -29.9% for Oil, 4.2% for Gas and 135.3% for Coal, the decrease in Oil consumption is due to decrease in production (HDIP energy year report,2020). So this consumption rate is quite high, and depletion of these resources is becoming a major concern for government.

Thus, the Problem lead us towards different research questions such as

1) What will be the demand of Crude Oil, Coal and Natural Gas in Energy Sector for Pakistan in upcoming years i.e. till 2030?
2) What are the other factors that affect the demand for Fossil Fuel in Energy Sector?
3) Is Fossil Fuel a sustainable Source for producing Energy in future for Pakistan?
4) How would these projected results in the future help the government by taking better decision for sustainable energy goals by analyzing the Latest Energy policy 2019., and would suggest better policy measures?

1.4 Objectives of the Research

As the world is shifting towards Renewable Energy sources, and natural resources are depleting for a country like Pakistan which depends majorly on Fossil Fuels for Production of Energy, this could very disastrous if natural resources would deplete completely so to stop that from happening, we must forecast the future consumption of these Fossil fuels in Energy Sector. If the forecast would tell us that the rate is increasing, we could recommend some urgent policies to government regarding quickly shifting from Fossil Fuel to renewable Energy as main source. So the objectives that we must complete in order to forecast the future consumption of fossil fuel are.

1) By using ARFIMA-B model, projecting the demand of Crude Oil, Coal and Natural Gas in Energy Sector of Pakistan in upcoming years i.e. till 2030
2) To find the impact of different determinants such as Reserves, Import, Prices and Production on the consumption of Crude Oil, Natural Gas and Coal in Pakistan
3) To find out the Sustainability of Fossil Fuel in powering the Country’s energy sector.
4) To suggest Ministry of Energy, some valuable policy points, which would help the government in making better decision about the energy production in the future.

1.5 Organization of the Thesis

Chapter 2 Presents the Literature Review, Chapter 3 will give overall analysis and forecasting results, Chapter 4 will be Qualitative Analysis, Chapter 5 would be Conclusions and Discussions and Chapter 6 will be Policy Brief

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Several studies have been conducted on modeling and forecasting the energy demand in developing and developed countries using different Econometric Techniques. The most used studies were time series models, linear regression models. Log linear models, partially adjusted regression models and fuzzy regression models to forecast future energy demand. Most commonly used technique is Auto-Regressive Integrated Moving Average (ARIMA) which could be used on time series data which shall be stationary. (Khan 2015)

In case of Pakistan, there is much scarcity on studies that forecasted the demand of Gas, coal and oil in Energy Sector in Pakistan. This study is of much significance as Pakistan energy sources constitutes of 73.9% of fossil fuels. (Pakistan Energy yearbook 2020). Thus, it is especially important to examine, based on past data, how much of Coal, Gas and Oil will be needed in 2030 to fulfil the demand of energy in the country.

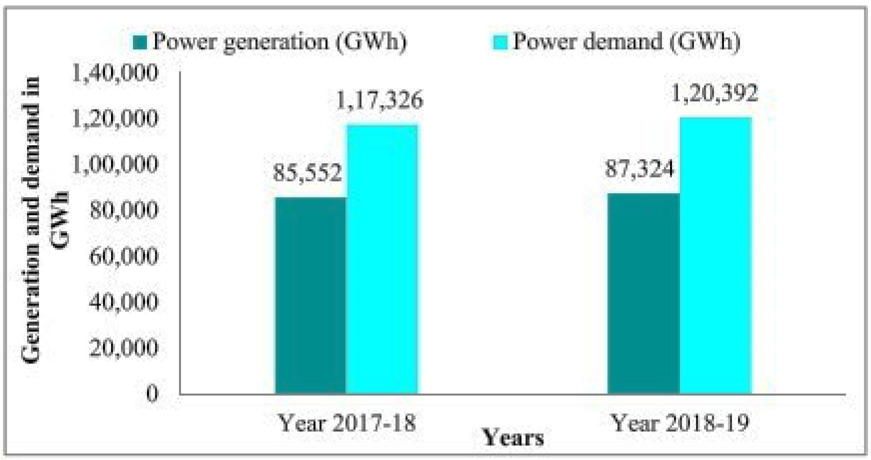

***Fig.2.1*:** Comparison of Power Generation and Power Demand. (Rehman, Ma et al. 2021)

Fig.2.1 shows an increasing trend in the power generation and power demand of Pakistan for 2017-18 and 2018-19. As energy consumption in Pakistan was rising from 1992-2015, So estimating the demand of fossil fuel in energy sector for future has become important.

2.2 Related to Methodology

Different Econometric Methodologies have been used to forecast the energy demand related to Coal, Oil and Gas. ARDL is used by some studies to forecast energy consumption (Lin and Li 2020), (Raza and Lin 2021), (Rehman et al 2021), (ADAD and RS). This model is based on the standard least square regression method in which lags of both dependent as well as independent variables are included. It is mainly used to find cointegration among variables and also applicable on stationary as well as non-stationary time series with mix order of integration. (Bentzen and Engsted 2001). ARIMA model is being frequently used to forecast Energy Demand and consumption(Noureen, Atique et al. 2019), (Nepal, Sharma et al. 2020), (Atique, Noureen et al. 2019), (Jamil 2020),(Mitkov, Noorzad et al. 2019). The main phases of forecasting procedure using ARIMA are data examination and transforming data to stabilize variance, test for stationarity check, estimation and testing, ACF/PACF plot examination, validation of model, error tests and finally forecasting results. This technique was first introduced by Box and Jenkins in 1976 which consists of mainly two parts, AR means Auto-Regressive whereas MA means Moving Average, the main parameters are **p** (lag observations in the model), **q** (the size of moving average) and **d (**the degree of difference) whereas the parameters **p** and **q** can be obtained by looking at Autocorrelation and Partial Autocorrelation function plot. If the data is already stationary, then we can use ARMA otherwise the data will need to be converted into stationary to estimate with ARIMA model. The projected values are estimated based on the past values of the variable itself, the residual values and it is used for univariate analysis. (Nwankwo, 2014). One Study found that ARIMA is better in forecasting energy demand than Holt-Winter model and LEAP methodology. (Rehman, Cai et al. 2017). Another Software used to predict future energy demand and supply is Long Range Energy Alternative Planning System (LEAP). It is frequently used by Different Studies (Emodi, Emodi et al. 2017)(Rehman, Cai et al. 2017, Raza, Khatri et al. 2022), to forecast energy demand in their respective countries. It is used mostly on macro-economic data and variables and also can perform different type of analysis like Demand Analysis, Transformation Analysis, Resource Analysis and Environmental Analysis. (Perwez, Sohail et al. 2015).

2.3 Related to Theory

2.3.1 Coal:

2.3.1.1. Context of Pakistan

Being a developing nation, Pakistan is currently facing serious energy problem in context of country's economic and social development. In Pakistan, coal is the safest and most reliable energy source and has major share in other fossil fuels such as oil and natural gas. Additionally, with the popularization and application of advanced and new technology, coal production costs are decreasing and will continue to decline in the future. It must be noted that new energy sources, such as solar energy and nuclear energy, still comprise a very low proportion of the energy structure; hence, these energy sources will fail to meet Pakistan's energy needs in the near term, and it will be a long time before these technologies can be industrialized on a large scale. In this sense, as a traditional energy source, coal will remain the main source of energy consumption in Pakistan at least for next two decades.

There are number of studies published to forecast coal demand in Pakistan. Asghar applied the error correction model (ECM) to examine the relationship between coal consumption and economic growth in Pakistan, India, Sri Lanka, Bangladesh and Nepal over the period 1973–

2003 (Asghar 2008). Using Toda and Yamamoto (1995) Granger causality tests, he found unidirectional causality running from coal consumption to economic growth only in Pakistan. Khan and Ahmed (2009) examined the demand for energy at disaggregate level (gas, electricity and coal) for Pakistan over the period 1972–2007 (Khan and Ahmed 2009). Their results based on VAR Granger causality suggest that both real income and domestic price level causes coal consumption in the short run. In an interesting study, Masih and Masih (1996) examined the link between energy consumption and economic growth for six Asian countries including Pakistan. They found a bi-directional causality between energy consumption and economic growth in Pakistan. SAU Rehman et al. have developed three different models to forecast energy demand such as coal, natural gas and oil (Rehman, Cai et al. 2017). These models include Autoregressive Integrated Moving Average (ARIMA), Hot-Winter and Long-range Energy Alternate Planning (LEAP). They concluded that ARIMA has more accurate coal demand forecasting than Hot-winter and LEAP models. Similar forecasting has been done by Raza and Shah by using different models such as Autoregressive Distributed Lag model (ARDL) and Vector Error Correction model (VECM) (Raza and Shah 2020). They have concluded that the GDP and coal consumption has bidirectional causality in the short term and well as long term. Lin and Raza (2020) used LMDI (Logarithmic Mean Divisia Index) and I-O Models to analyze the change in coal consumption from 1989-2018. They find that power sector of Pakistan has contributed significantly to consumption of coal in current years and the consumption rate of coal is increasing with the rate of 6.2% from production and 29.8% from imported coal.

2.3.1.2 Context of other countries:

Similar studies have been conducted for other nations to evaluate coal consumption and future demand in other parts of the world, such as Duan and Luo, who have developed a multivariable model for predicting coal consumption. They hypothesized that population size and local economic development are the major factors that significantly affect coal consumption (Duan & Luo, 2022). Their results indicate that the multivariable prediction model is more precise than previously developed models, including NLARX and ARIMA. A similar model was proposed by Tong et al. in 2022 for three larger economies, i.e., China, USA, and India (Tong, Dong et al. 2022). They optimized their model using a Simulated Annealing Algorithm (SAA). They concluded that coal consumption would increase in China and India for the next five years but decline in the USA. Moreover, they have also shown that their prediction model has a lower error percentage of 3.12% than other models. Other researchers have used a different approach to predict coal consumption in Iran (Shakibaei, GhasemiNejad, et al. 2021). They have considered different socio-economic factors for developing their improved computation model optimized by a hybrid approach. They have shown that their proposed optimized computation model is an excellent and reliable tool for coal consumption prediction in Iran. Mou (2021) analyzes China's conversion from coal to gas to produce energy based on a distribution model. Their study shows significant changes will occur while shifting from coal to gas. Li et al. have proposed a combined linear modified linear (MGM-ARIMA) and linear modified non-linear (BP-ARIMA) model for the prediction of coal consumption by Engle-Granger by 2030 (Li, Yang, et al. 2019). S. (2019) analyzed demand trends of coal in critical regions. He found that renewable energy sources will not affect China and India's share of coal in producing energy. The prediction model shows that coal consumption in India will continue to increase at an average annual rate of 2.5% from 2018–2030. Similarly, a coal demand forecasting model was proposed by Li in 2019 for China (Li & Li, 2019). Gravitational Search Algorithm has optimized the model, and it concluded that their model is effective in coal demand forecasting by empirical and comparative analysis.

2.3.2 Natural Gas:

2.3.2.1 Context of Pakistan

Natural gas is a crucial energy source in Pakistan, accounting for a significant portion of the country's energy mix. The energy sector in Pakistan heavily relies on natural gas for electricity generation, industrial processes, and domestic heating. Despite its abundance, Pakistan needs more natural gas due to increasing demand, inefficient usage, and supply constraints. Due to limited reserves of gas, the huge demand has resulted in load shedding, blackouts, and increased use of alternative and expensive energy sources. Analyzing the current natural gas consumption patterns in energy is essential in this context.

Khan (2015) forecasted the natural gas demand for Pakistan using the OLS regression technique using data from 1978-2011. He found that Natural Gas consumption in the power sector will reach 734,062 million cubic feet by 2020, the highest among the transport, residential, industrial, commercial, etc. Furthermore, an increase in the price of natural gas will reduce per capita natural gas consumption significantly in the forecasted time (2012-2020), and the growth rate of gas consumption will increase from 0.28% to 8% in 2020. Hussain et al. (2022) forecasted sectoral-based natural gas demand in Pakistan for 2016-2030. The author used ARIMA and Holt-winter methodology for forecasting and compared both models' Mean square root error. He concluded that ARIMA is the most appropriate model for energy forecasting with minimum MSE.

Several studies analyzed the relationship between Natural Gas consumption and Economic growth in Pakistan by using ARDL methodology. The results show that a long-run relationship between variables and natural gas consumption positively affects economic growth in Pakistan. (Shahbaz et al.2013; Shahbaz et al.2014). Raza and Lin (2022) estimated natural gas consumption factors in the case of Pakistan. The study used the Logarithmic Mean Divisia

Index and sectorial Intensity Decomposition Methods for estimations. The results show that energy is the most significant factor in Gas consumption, followed by GDP per capita, population, etc. The study further predicted that the average yearly gas consumption growth rate will be approximately 24.37% from 2020 to 2030.

2.3.2.2 Context of Other Countries

Natural gas is a critical component of the energy mix in many countries around the world. It is a cleaner and more efficient source of energy compared to coal and oil, making it an attractive option for electricity generation, heating, and industrial processes. Countries such as the United States, Russia, China, and Iran are among the largest natural gas producers and consumers in the world. The consumption patterns of natural gas vary among these countries, with some relying heavily on natural gas for electricity generation and industrial processes, while others use it primarily for domestic heating and cooking. Despite its many advantages, natural gas consumption in some countries is facing challenges such as supply constraints, environmental concerns, and the need to transition to renewable energy sources.

Zheng et al. have proposed a nonlinear grey Bernoulli model for the production and consumption forecasting of natural gas for North America. Although the model has been developed for short term forecasting, its prediction is accurate as compared to other model (Zheng, Wu et al. 2021). Fig.2.2 shows the natural gas production and consumption forecasting for Natural gas for North America.

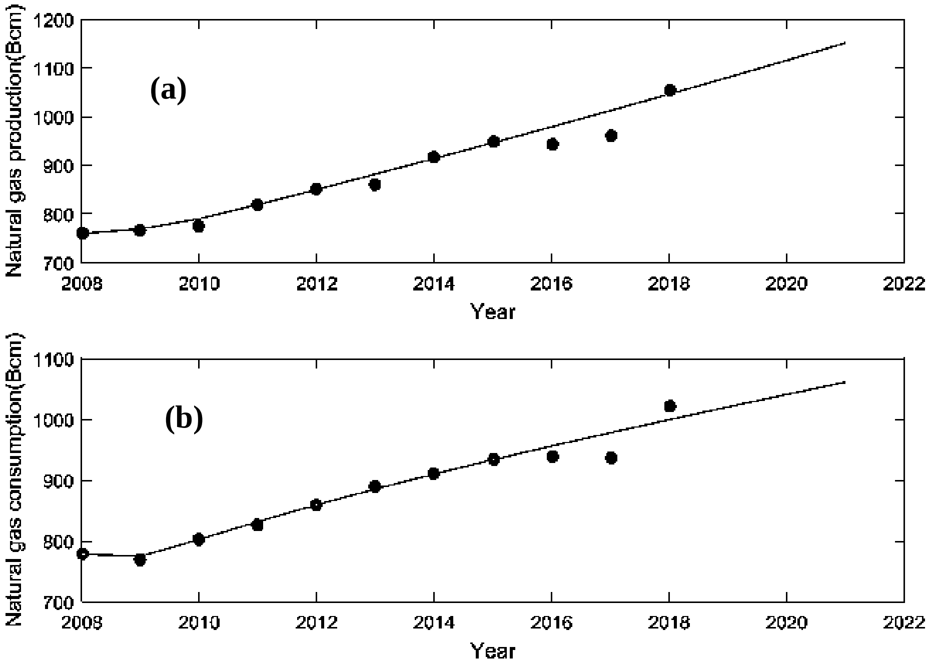

***Fig. 2.2*: **Prediction Results of Natural gas (a) production (b) consumption (Zheng, Wu et al. 2021)

Kostakis et al. (2021) examines the natural gas demand of residents of Greece from 2012-2019 (Kostakis, Lolos et al. 2021). The study concluded that gas demand of resident people is price inelastic but income elastic. Moreover, weather conditions and urbanization affect the gas demand. Lin and Li have studied natural gas demand using ARDL with data ranging from 1985-2017; they found that China's subsidy on natural gas amounted to CNY 73 billion till 2017 (Lin and Li 2020). Wang et al. (2019) use the SVM technique to forecast future natural gas consumption for China; The study shows rapid growth in gas consumption in coming years. Erdogdu (2010) examines the demand and forecasting of natural gas in Turkey using ARIMA modeling from 1987-2017. His study concluded that the gas consumption of Turkey increased tremendously from 0.5 billion cubic meters (bcm) in 1987 to reach 35 bcm in 2007; his study also forecasted that people do not respond to changes in the price of gas as there is a monopoly in Turkey, so they have no choice.

2.3.3 Crude Oil:

2.3.3.1 Context of Pakistan

Crude oil is an essential component of the energy mix in Pakistan, accounting for a significant portion of the country's energy consumption. Pakistan relies heavily on crude oil imports to meet its energy needs, with most of the imported oil used for transportation, industrial processes, and power generation. Despite the country's significant crude oil refining capacity, Pakistan has been facing an oil shortage due to increasing demand, supply disruptions, and inefficient usage. This has resulted in frequent power outages, increased reliance on expensive alternative energy sources, and a burden on the country's economy. In this context, it is crucial to analyze the current crude oil consumption patterns in Pakistan's energy sector to identify the challenges and opportunities for sustainable and efficient usage while also exploring alternative energy sources to diversify the country's energy mix.

The authors find small literature on oil forecasting and demand in the case of Pakistan. Raza and Lin (2021) analyzed the factors affecting oil import for Pakistan using the ARDL technique and data from 1986-2018. They find that the crude oil dependency of Pakistan will rise by 0.07% every year, and the dependency rate will be 76% till 2035; he also estimates the oil demand to be 18.0465 MToe in 2035. Asif et al. (2020) analyzed the determinants of import demand for crude oil in the case of Pakistan. Co-integration technique is used to estimate the long-run relationship between crude oil import demand and its determinants. The results suggested import demand for crude oil is positively and significantly affected by the GDP per capita of the country. Price and real Effective exchange rate have negatively and significantly impacted the import demand of oil.

2.3.3.2 Context of Other countries

Oil consumption is a critical issue for the energy sector worldwide, with many countries heavily reliant on oil for their energy needs. Given the environmental and economic implications of oil consumption, a vast body of literature has emerged on the topic, exploring factors that drive oil consumption in different regions of the world and the impacts of oil consumption on energy security, economic growth, economic growth, and the environment. By synthesizing and analyzing the existing literature, this review seeks to contribute to a better understanding of the complex and multifaceted issues related to oil consumption in the world's energy sector.

Recently, Li et al. have proposed a multivariable grey prediction model for oil consumption forecasting in China from 2020-to-2024 (Li, Liu et al. 2022). The prediction from the present model is compared with other prediction models, including computation models, ARIMA, grey linear model, and non-linear models. The results of the models show a significant rise in the crude oil demand to about 24% at the end of 2024. A similar type of novel fractional grey forecasting model was developed by Wang et al. in 2022 (Wang, Zhang et al. 2022). Crude oil consumption forecasting has also been done for a minor economy, i.e., Poland (Manowska & Bluszcz, 2022). The artificial neural network approach has been adopted to forecast crude oil consumption. Fig.2.3 presents the forecasting trend for the Polish market till 2040 and shows an increasing non-linear trend as predicted by the current model. Oil consumption is a critical issue for the energy sector worldwide, with many countries heavily reliant on oil for their energy needs. Given the environmental and economic implications of oil consumption, a vast body of literature has emerged on the topic, exploring factors that drive oil consumption in different regions of the world and the impacts of oil consumption on energy security, economic growth, economic growth, and the environment. By synthesizing and analyzing the existing literature, this review seeks to contribute to a better understanding of the complex and multifaceted issues related to oil consumption in the world's energy sector.

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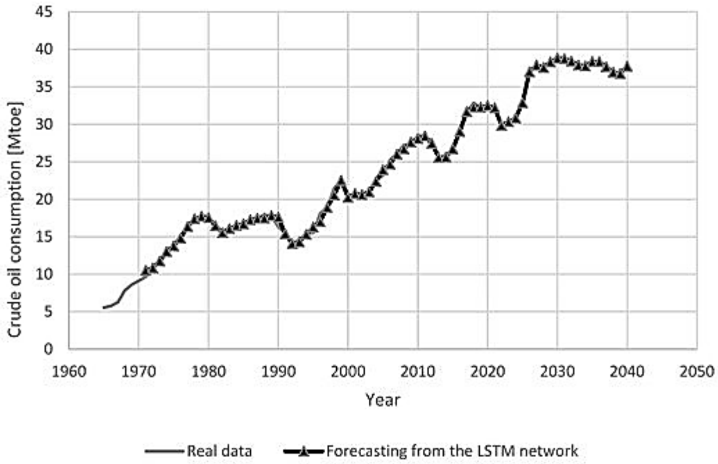


Fig.2.3: Crude oil consumption forecasting for Poland

Dritsaki et al. (2021) have developed different ARIMA models for crude oil consumption forecasting for Greece. Forecasting is attained with static and dynamic procedures in and out of the sample using all the forecasting criteria. The results show a sharp drop in the coming years due to efforts currently being made to replace crude oil with other forms of energy. Another computational approach for crude oil future demand is proposed (Al-Fattah & Aramco, 2021). The model was developed and applied to two country cases, one for the high crude oil producer (Saudi Arabia) and the other for the high oil consumer (China). The input variables of the proposed computational model include the gross domestic product (GDP), the country's population, oil prices, gas prices, transport data, transformed variables, and functional links. The forecasting models show that the crude oil demand for both Saudi Arabia and China will continue to increase over the forecast period but with a mildly declining growth, particularly for Saudi Arabia. This decreasing growth in the oil demand can be attributed to increased energy efficiency, fuel switching, conversion of power plants from crude oil to gas-based plants, and increased utilization of renewable energy, such as solar and wind, for electricity generation and water desalination.

2.3.4 Energy Consumption and Demand in Pakistan:

Several studies have explored the drivers of energy consumption and demand in Pakistan, such as population growth, urbanization, and economic development. The impact of energy consumption on the environment has also been a key area of research, particularly in relation to Pakistan's elevated levels of air pollution and greenhouse gas emissions. Additionally, there have been studies on the challenges facing Pakistan's energy sector, including the limited availability of domestic energy resources, inadequate energy infrastructure, and policy issues. Researchers have proposed various solutions to address these challenges, such as promoting renewable energy sources, enhancing energy efficiency, and improving energy governance. Overall, the literature on energy consumption and demand in Pakistan highlights the complex and interrelated nature of energy issues and the need for a comprehensive and integrated approach to energy policy and planning.

Shabbir et al. (2018) use Wavelet Coherence Analysis to analyze the relationship between technological innovation and energy demand in Pakistan using data from 1997-2016; they find that innovation helps change the demand for energy in the country. Raza et al. (2022) examine Balochistan's demand and future energy production from 2008-2018 using the LEAP methodology. The study reveals that the total assets of the natural gas present are 392 TWh

(Terawatt-hour), 84 TWh for solar capacity, and 22TWh for coal. Rehman et al. (2021) examines the relationship between sector-level energy consumption and economic growth using the econometric technique of ARDL, the granger causality test, and VECM from 1980-2016. Their studies reveal a positive relationship between the power sector and oil consumption. One of the relevant studies is Rehman and Deyuan (2018), which uses the time series technique and a simple linear model to forecast the energy consumption of oil, gas, electricity, and coal. His results concluded that the government needs to give special attention to Pakistan's energy sector and introduce new policies to meet the country's demand. Rehman et al. (2017) uses the STELLA technique to estimate Hubbert peaks for coal and oil consumption using data from 1971-1992. They concluded that coal is the most abundant type of fossil fuel in Pakistan, with 134.06 million tons; meanwhile, oil is the less available resource in the country; they also found that Coal and Gas are not enough to fulfill the energy demand of the country, Bhutto et al. (2017) uses ARIMA technique to find out the consumption of gasoline in transportation sector from 1991-2014. The study shows that the annual increase in consumption of gasoline would rise to 6.21 Mtoe (Million tons of oil equivalent) in 2025-2026 from 4.50 Mtoe in 2013-2014. Similarly, Wahid et al. (2017) uses ARDL and ARIMA technique to forecast the consumption of coal using time series data from 1972-2015. Their findings show the increasing trend in usage of coal from 2016-2030.

There have been sufficient debates in PIDE over the years on energy situations in Pakistan. Misbah Rashid (2022) from PIDE published an article on energy security related to comparing Imported Coal and Thar Coal. The article tells us that Pakistan has the 28th largest coal reserves in the country, yet 70% of the requirements of coal are fulfilled by imports. Further, the fuel import bill has crossed twenty billion dollars in FY 2022. The article recommends that coal power plants' efficiency should be improved immediately, and power harnessing technologies from indigenous coal should be properly deployed. Afia and Usman (2022) discussed the Gas crisis in Pakistan in a knowledge brief published in PIDE. They find that Gas demand in the overall country has increased, but exploration and production of gas have declined significantly. The demand in sectors is facing mismanagement issues like Gas allocation preferences depending on political motivation; prices are much subsidized for sectors, and further, the inefficiency of sectors results in inefficient use of Gas. The power sector is second on the priority list of allocation. Further, Supplies are facing significant issues like LNG import complications and depleting Gas resources in the country. Furthermore, LNG operational infrastructure is not robust, and thus, it results in inefficiency and increased supply costs. Another chapter published by Afia Malik (2021) in PIDE monographic series shows that the transport sector is the primary user of petroleum products, which is 76%; the power sector is second, using 14% of the petroleum products for power generation. They further find that in 2019, the power sector was the top consumer of Natural Gas, followed by the domestic sector. However, inefficient government policies resulted in the vast consumption and demand of Gas in the domestic sector specifically because of exceptionally low tariffs. Furthermore, the usage of Gas is very inefficient because of the weak infrastructure of Gas at the domestic level, which results in not only high costs but interruptions in the supply chain.

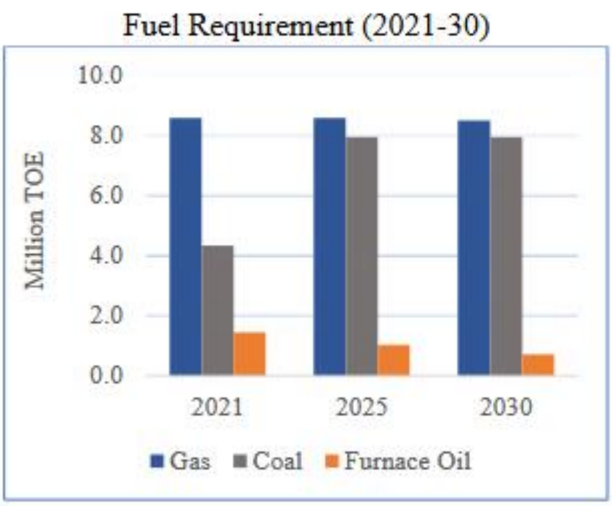


Fig.2.4: Fuel requirement forecasting (Ministry of planning report)

As per author’s knowledge, there is only two studies that attempts to forecast the Energy demand from each fossil fuel in Energy sector of Pakistan for upcoming years. One is by using

OLS (IEP Report-1, Ministry of Planning, 2021). He finds out that Oil requirement will go down in future for energy production, Gas consumption will remain same and Coal demand will increase drastically. (Fig2.4). He further recommended that OLS methodology does not deal with outliers accurately and thus recommended that same study could be done by using Autoregressive Moving Average forecasting techniques.

After that, another report is being published by Ministry of Planning, Development and Special Initiatives in 2021(IEP Report-2, Ministry of Planning, 2022) which forecasted the future Crude oil, Natural Gas and Coal consumption in Energy sector of Pakistan by using SARIMAX and monthly time series data. Seasonal component was included along with Exogenous variables like GDP, Energy Prices, Population etc. The results show that 33 percent of Furnace Oil Share in Energy Production will be phased out by 2030. The forecast results show that Natural Gas including LNG usage for energy production will decrease from four hundred billion CFt in 2020 to 200 billion CFt in 2030. For Coal, the results show that more than 70 percent of energy production will be met by coal power plants in which 45 percent would be local coal and 25 percent would be on imported coal.

2.4 Summary/Literature Gap

The existing literature does not analyze structural breaks in the data while forecasting fossil fuel consumption in Pakistan's energy sector, which is a considerable discussion in the time series analysis. Forecasting time series variables with exogenous breaks and outliers show less Root Mean Square Error and Mean Absolute Percentage Error than the forecast without checking breaks in the data. Asghar and Urooj (2012) forecast the Wheat and Rice Prices in Pakistan using ARIMA modeling with Outliers and Exogenous breaks included using Autometrics. They concluded that forecast shows better results when breaks are captured by using automatic modeling (General to Specific modeling), and outliers are identified with large residuals, which, in return, results in better projections in future years.

The significance of the study is that, unlike other studies, this study incorporates two types of breaks to analyze structural breaks in the data while forecasting the Consumption of Crude Oil, Natural Gas, and Coal in the case of Pakistan. The study proposes the ARFIMA-B model for future projections of Oil, Gas, and Coal (ARFIMA-B is abbreviated as Autoregressive Fractionally Integrated Moving Average with Breaks). When the Author analyzed the series of consumption of Crude Oil, Natural Gas, and Coal, two types of breaks were found in the data (We found step shifts and sudden shocks). One is the Step indicator saturation technique used while checking co-integration among Dependent and Independent Variables. This technique is used when we see shifts in the series due to Government Intervention or Policy implementation. Further, the Impulse Indicator Saturation technique is included. This technique is used to check sudden shocks in the series. Our results show significantly different results than the studies done by the Ministry of Planning, Development, and Special Initiatives that used OLS and SARIMAX for forecasting. Including dummies shows better in-sample forecasts and future projections are improved graphically.

The methodology of our study is to make projections with secondary annual time series data gathered from two sources. One is from World Bank Indicators, and the other is from Pakistan Energy Yearbook (different editions). Data is taken from 1981-2021. Firstly, the breaks are identified separately with the help of the step indicator saturation technique, and then significant breaks are regressed with other exogenous variables on the endogenous variables. Furthermore, the impulse indicator technique is used to check shocks. Then the forecasting with the ARFIMA-B model is done with the inclusion of breaks for better and more accurate projections. The benefit of this methodology is that we can estimate large sample size data easily by using different time series techniques, and missing data could be inserted using calculations. This study will use suitable techniques such as ARIMA, ARIMAX, ARFIMAX, etc., alongside the Impulse Indicator Saturation technique to find breaks in the data and then forecast the demand for Oil, Coal, and Gas in the Country. Studies mentioned in the literature review prove ARIMA gives better results when forecasting with minimum RMSE (Root Mean Square Error) value as compared to other technologies such as ARDL, OLS, etc. ARIMAX can be used when there is more than one explanatory variable to estimate the dependent variable. The benefit of the ARIMA model is that it can give more suitable methods to model trend and seasonality properties in the data. ARFIMA can be beneficial if the data is needed fractionally converted into stationarity. In this thesis, we have used ARFIMA-B because B will represent the inclusion of multiple breaks in the data. Series will be converted into stationery if found non-stationarity in the data.

This study would give significant policy suggestions to the Ministry of Energy related to Fossil fuel usage as the main source of energy production. What alternatives could Government use to decrease its dependency on Fossil fuels as an energy source and could shift to Renewable Energy Resources? Two years ago, the Government of Pakistan published the "Alternative and Renewable Energy Policy 2019," in which it is predicted that Pakistan will increase its dependency on energy production of Renewable Energy resources by 20% in 2025 and 30% by 2030. According to a World Bank article in 2020, Pakistan should urgently shift to solar and wind power at least 30% in 2030 as it would be cheaper, would provide energy security, GHG Emissions would be reduced, and savings of $5 US billion dollars could be done in the next 20 years. With the estimated demand, the Government could take steps to immediately shift its primary source from fossil fuel to Renewable Energy sources in the coming years. (World Bank Report, 2020).

CHAPTER 3

METHODOLOGY, RESULTS & DISCUSSION

3.1 Methodology

The tests for checking stationarity in the time series would be modified Augmented Dickey-fuller test, which allows for a structural break in the data. This was introduced by Perron (1989), who argued that unit roots and structural change are related in some way and that classical ADF tests are biased and reject unit root null when data is trend stationary, including a structural break. This is a well-known test for checking stationarity in series having breaks in it. In our analysis, we want to find out whether the variables of each empirical model are stationary or not. By ignoring the presence of Unit Root with a break, we can mistakenly use the wrong co-integration test or projections technique. This could give us spurious regression results and inaccurate and unreliable forecasts, which could be of no use. Autometrics (General to Specific modeling) removes the insignificant variables from the regression results. We are using this methodology because this will give us only significant variables and significant breaks by removing the variables and breaks which are statistically insignificant and thus do not explain variations in the dependent variable. The Step Indicator Saturation Technique will be used to find step shifts in the data as our data has step shifts and shocks in the series, so SIS will help us find those shifts, thus improving the overall analysis and giving more accurate results. After that, we will use the Engle-Granger co-integration test for estimating empirical models by using the Ordinary Least Square methodology with breaks included. As all variables are stationary at the first difference, the appropriate test is the EG co-integration test, in which we can find long-run estimates of the model. The next step would be the Chow test which will help us in finding the stability of the parameters of our three empirical models. Unstable parameter values change with time, meaning overall models could be more stable and thus would give inaccurate results after running a regression. Error Correction Mechanism will be checked after running the EG co-integration test to help us determine whether disequilibrium will equalize itself in the short run. Finally, for forecasting, we will use the ARFIMA-B methodology. Below are the descriptions of these tests and how they work.

3.1.1 Modified DF test with exogenous break

The acronym of DF is “Dickey Fuller Test.” This test is a type of dickey fuller test which allows for single exogenous break in the data. It was first proposed by Perron (1989) who criticized the old ADF tests that in case of any structural break, the ADF tests are biased towards acceptance of null hypothesis. This test includes dummy variable to accommodate one known break in the data. Break point of trend is fixed and is chosen independently of the data. Perron (2005) further argues that this test is consistent to check for unit root whether there is a break or not. Based on his model, testing of unit root is done by estimating three equations. These equations have three types of structural breaks in the data. The first one is ‘crash’ model (Eq3.1). This model allows for single break in intercept or level of series, second one is ‘changing growth’ model (Eq3.2) which has a capacity to allow break in the slope (also known as rate of growth) and the third model (Eq3.3) which allow for both effects to occur together. These three equations are shown here.

$$x_t = \alpha_0 + \alpha_1 DU_t + d(DTB)_t + \beta t + \rho x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-1} + e_t \qquad (3.1)$$

$$x_t = \alpha_0 + \gamma DT_t * + \beta t + \rho x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-1} + e_t \qquad (3.2)$$

$$x_t = \alpha_0 + \alpha_1 DU_t + d(DTB)_t + \gamma DT_t + \beta t + \rho x_{t-1} + \sum_{i=1}^{p} \phi_i \Delta x_{t-1} + e_t \qquad (3.3)$$

Here, DU_t represents a change in level, $DU_t = 1$ if *(t>TB)* otherwise zero, the slope dummy DT_t represents shows change in slope of trend function, *DT*=t-TB* otherwise zero, if t=TB+1, then crash dummy *DTB=1* otherwise zero and break date is TB. These models have null hypothesis of unit root with a break as regression already incorporates dummy variables. Alternative hypothesis is broken trend stationary process.

This was further extended by Perron (1997) and Perron and Vogelsang (1992). These studies proposed a group of test statistics that allows structural breaks of two distinct kinds. One is Additive outlier (AO) which allows the mean to be suddenly changed (crash model) and the other one is Innovational Outlier (IO) which allows the mean to be changed gradually. These tests are based on minimum value of t-statistics on overall sum of co-efficients of auto-regressive over all possible break points.

3.1.2 Autometrics

This technique uses the concept of GETS modeling. In this model, general dynamic model is analyzed to get the main properties of data set then different standard testing methods are applied to remove the insignificant variables so that the complexity of the model can be reduced by checking the accuracy of reduction procedure at every stage.

Hendry and Krolzing (1999) uses Monte-Carlo Simulations to study the recovery of Data Generating Process (DGP) by checking the probabilities of *PcGets* and they found better results than tradition methods. Furthermore, the same authors in 2003 checks the consistency of *PcGets* procedure. Doornik (2009) introduces Autometrics, a third-generation algorithm with the help of same principles. The methodology of Autometrics is that it uses tree path search method to detect and remove variables which are statistically insignificant. The benefit of this method is that it does not stop in a single path whenever a relevant variable is removed inadvertently while keeping other variables as proxies.

The main concept of the working of Autometrics is that at first, all variables are included in the model (GUM-Generally Unrestricted Model). This model is then estimated by using

Linear Regression Technique and then different diagnostic checks are applied. In case of the presence of insignificant variables, simpler models are then again estimated using tree path reduction search and again diagnostic tests are applied. This process continues to run, and all survived terminal models are united and then same tests will be applied. If few models pass all the encompassing tests, then the selection of the model will be based on different Information Criterions which are pre-selected. In any case, if the number of variables exceeds the number of observations in the data, Autometrics uses the cross-block algorithm proposed by Hendry and Krolzig (2004).

3.1.3 Step Indicator Saturation Technique

The Step Indicator Saturation technique was first introduced by Hendry in 1999. Later in 2012, Doornik properly developed the study of SIS to capture the breaks. He used Monte-carlo simulations and proves the ability of SIS in capturing breaks on different aspects such the detection's accuracy when local shift happens and specially improving the acceptance frequency as compared to Impulse Indicator Saturation Technique (IIS) It is known as a general to specific approach used for finding unknown break numbers in the data which occur at unknown time periods and with unknown magnitudes and durations. Basically, step indicators are the accumulation of different impulse indicators leading to each of the next observations. In the regression model, the T-1 step shift indicators with saturation settings are included. It took the form. The 'T' step of $i_T = (1,1,1,1 \ldots,1,1)$ is known as the intercept whereas the step indicators get the form of $i_1 = (1,0,0 \ldots,0), i_2 = (1,1,0 \ldots.,0) \ldots \ldots i_{T-1} = (1,1,1,1 \ldots\ldots,1,0)$

Assume $y_t = c + \varepsilon_t$ where ε_t is the normal and independently distributed error term with mean as zero and variance as σ^2. Then the below equation can be presented as Eq 3.4

$$y_t = c + \Sigma_{k=1}^{\frac{T}{2}} \delta_{lk} S_t(k) + \varepsilon_t \qquad (3.4)$$

According to the split half approach, Eq (3.4) shows the first T/2 parameters to be analyzed. First step is that any step indicator (S_t) with less t-value as compared to the critical value α will be deleted. Next step is to estimate and eliminate the next remaining half of the indicators (S_t). The filtered model having significant step indicators is combined and then again estimated to give final model. This technique deals the structural breaks as part or segment of step indicators.

3.1.4 Impulse Indicator Saturation Technique

This technique was first devised by Johansen, Hendry and Santos in 2007. This technique was also known as Generally Unrestricted Model (GUM). This technique is basically used to find level shifts, single break, multiple break and outliers in the data. The working principle is that one dummy variable is being created for each data point in the data to check for structural breaks or outliers in the data then it runs regression to check for significant breaks. After that a second dummy variable is being introduced and regression runs again. This will help the technique to remain unviolated. For our convenience, we have set a significant level of 1% percent. Final regression results will show us significant breaks which would help us in modelling the data and analysis better. Usually, it is assumed that error is normally distributed which mostly proves wrong in case of real data analysis. (Ghouse et al. 2021). Below equation will show how IIS technique introduces impulse dummy to each data point of the series. Suppose α is intercept in the model, y is the dependent variable which is continuous in nature and x_{ji} is orthogonal regressors where *i* = 1,2,3…n and *j* = 1,2, 3,….k then the below equation can be written as Eq.(3.5)

$$y_i = \propto + \sum_{j=1}^{k} \beta_j x_{ji} + \sum_{i=1}^{n} \gamma_i I + \varepsilon_t \qquad (3.5)$$

In which *I* is the identity matrix for each observation in the series

$$I = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3.6)$$

3.1.5 Engle Granger Co-Integration test (2-step procedure)

Engle and Granger (1987) first develop this procedure. They noted that linear combinations of two series which are I(1) at level, is stationary or I(0) which suggested that series are co-integrated. This linear combination defines a co-integration equation with co-integrated vectors of weights showing the long run relationship between variables. Let y_t and z_t are two variables in x_t vector and they are I(1). The methodology will check whether the two variables are co-integrated of order CI(1,1).

The components of the vector x_t are said to be co-integrated of order (d,b) i.e. x_t~*CI(d,b)* if

1) All components of x_t are I(d)
2) There exists a vector *b(≠0)* so that *m=b'*x_t*~I(d~b), b>0.* This vector *b* is called the cointegrating vector.

In other words, we try to find out the coefficients and constant in a way that Eq 3.7 is stationary.

$$u_t = \sum_{j=0}^{n} \alpha_j x_{j,t} + c \quad (3.7)$$

If u_t is stationary, then the whole equation is stationary irrespective of the constant value.

If the variables are found to be co-integrated, residuals will be saved after running the regression procedure on Eq. (3.8)

$$y_t = a_0 + a_1 x_t + e_{1,t} \quad (3.8)$$

After regression, test for unit root in the residuals

$$\Delta e_{1t} = a_1 e_{1t-1} + v_{1,t} \quad (3.9)$$

If unit root is found in the residuals, we could not reject the null hypothesis that variables are not cointegrated.

3.1.6 Ordinary Least Square Method

Ordinary Least Square Method is generally used for estimating linear regression coefficients. It describes the relationship between independent variables and dependent variables. The term 'Least Square' refers to minimum SSE (sum of squared estimate of error). This method was first published officially by Adrien-Marie-Legendre in 1805 but it is also credited to Carl Friedrich Gauss who develops it in 1975 who improves the significance of the method.

The OLS general Equation can be written as Eq 3.10

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i, \text{ where i=1,...,N} \quad (3.10)$$

We used the available data to find estimates of Intercept (β_0) and Slope (β_1) and co-efficients of parameters to find out the impact of independent Variables(X_i) on Dependent variable(Y_i)

3.1.7 Chow test

This test was first developed by Gregory Chow in 1960. This test used f-test value to analyze whether single regression results are more efficient than two separate regression results by dividing the sample into two sub-samples. This test is based on the evaluation of Chow's ratio and its mathematical expression is as follows (Eq. 3.11)

$$F^* = \frac{SSR_r - {SSR_{ur}}/{K}}{(n_1 + n_2 - 2K)} \quad (3.11)$$

Where,

$SSR_r = Restricted\ Sum\ of\ Squared\ Residual$

$SSR_{ur} = Unrestricted\ Sum\ of\ Squared\ Residual$

$K = Number\ of\ Parameters$

$n = No. of\ Observations$

3.1.8 ARIMA, ARFIMAX, ARIMAX(p,d,q)

The acronyms of ARMA, ARIMA, ARFIMAX and ARIMAX is "Auto-Regressive Integrated Moving Average" or "Auto-Regressive Fractionally Integrated Moving Average." It was first developed by George Box and Gwilym Jenkins in 1970s, hence called Box Jenkins approach. The notations "p,d and q" represents the parameters of the model. These are the econometric models used to forecast the future trend and values of the variables with the help of past values and residuals to improve the forecasting of the model. The difference between ARIMA and ARIMAX is that ARIMA is univariate analysis and ARIMAX is multivariate analysis means there could be more than one explanatory variable to predict the future values. It is somehow like the multivariate regression model.

The general ARIMA(p,d,q) model would be represented in Eq 3.12 as

$$X_t = c + \varepsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} \quad (3.12)$$

Where φ shows the autoregressive model's parameters, θ means the moving average model's parameters, c is the constant, Σ is summation notation and ε is error terms (white noise).

The general ARIMA model does not need independent variables to forecast for future, instead it uses information contained in the series to project for future. If independent variables were included in the model, then the model would convert into ARIMA-X in which X shows the number of independent variables needed to forecast results. Table 3.1 tells us the properties of MA and AR lags in ACF and PACF plot.

Table 3.1: AR, MA, ARMA properties

Properties	**AR (p)**	**MA (q)**	**ARMA (p, q)**
ACF	Decay	Cuts after q lag	Decay
PACF	Cuts after p lag	Decay	Decay

As mentioned in the literature, many techniques were utilized to forecast energy demand or fossil fuels using different econometric techniques such as LEAP, ARIMA, VAR etc. The basic procedure for time series forecasting is to check whether times series is stationary or not. Because nonstationary time series would give spurious results, if not stationary, we will use ARIMA model which will estimate the value of d as one. Next step is to check whether different variables of OIL, GAS and COAL models are co-integrated or not. It will show us whether independent variables affect dependent variables or not. We will use OLS methodology to determine it. Next and final step is to forecast the 3 models using ARFIMA-B(p,d,q) technique which would give us the trend of these three fossil fuel consumptions in next 9 years.

The source of the data are multiple editions of Documents published by different Ministries of Pakistan i.e. Pakistan Energy Yearbook, World Bank Indicators etc. Relevant Studies collected data from these types of sources as they are issued by Government Ministries which are being highlighted in the literature review. Further, the category of the data is Secondary type annual time series. Time period has been taken from 1981-2021. Only import of LPG in Gas consumption model has data from 1993 so regression analysis could only be possible on the variables with data taken from 1993 to 2021.

3.1.9 Trend in the consumption of Oil, Coal and Gas

We can see in Fig. 3.1 below that Consumption of Oil increases with the time except on two-time period, one in 2004 where the steep decline shows the declination of Furnace Oil consumption to 47% because of increase in Natural Gas supplied in 2003 and reduction in production of Oil in that year. (HDIP, 2003). The decreasing trend from 2017-2019 shows the less supply of Oil and Dwells in that year and the government plan to decrease the share of furnace oil as low as 10% in overall energy mix and replace it by Coal in producing energy. (PES 2019). Coal, on the other hand, shows an increasing trend after 2016 because it was cost effective in producing energy as compared to Oil (Raza & Shah, 2019). Natural Gas consumption increased after 2005, because major power plants were shifted to gas fuel and different sectors including transportation were converted majorly to gas, so consumption increases at that time. After 2017, the downward slope shows the supply of Gas was short and less wells were discovered as compared to previous years.

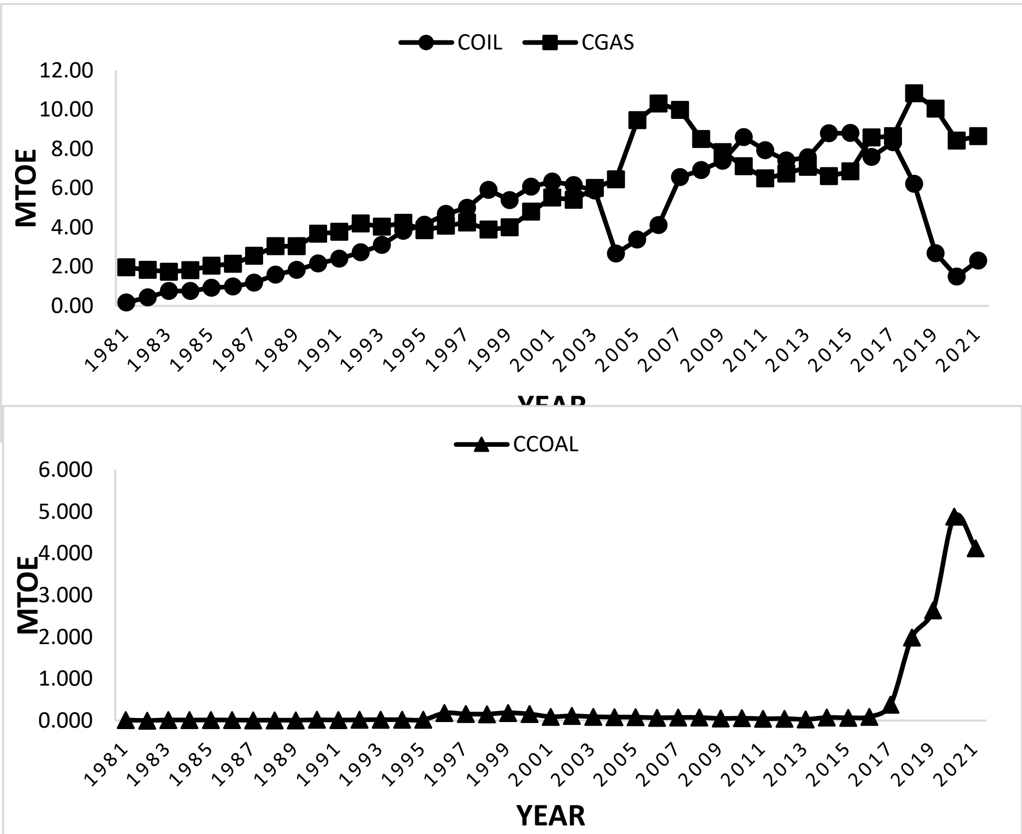


Fig.3. 1 Consumption of Fossil Fuel in Energy sector in Pakistan

3.2 OIL

The Graphical presentation of different variables of Oil Consumption model is shown in fig. 3.2. The C_{OILt} is consumption of Oil which is measured in MTOE (Million Tons of Oil Equivalent), R_{OILt} is Reserves of Oil which is measured in Million Barrels, PrOIL is Local Production of Oil which is also measured in Million Barrels, IOIL is Import in Million Tones, PeOIL is Price of Furnace Oil in Rupees per Ton and GDP is GDP per capita measured in current LCU.

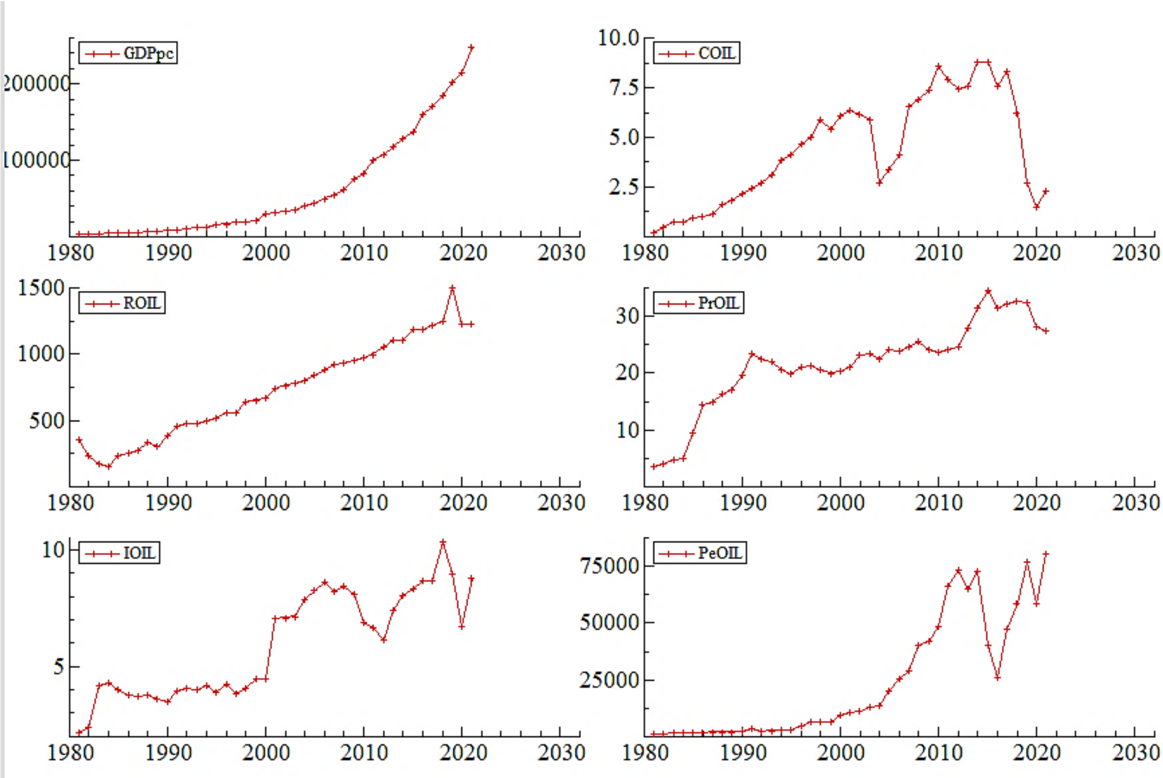


Fig. 3.2: Graphical Presentation of Different Variables of Oil Model

In Fig. 3.2, Consumption of Oil (C_{OILt}) is showing major shocks in 2004 and 2020, showing less production in 2004 and 2020, The dwells were discovered less than 30% from previous years. This resulted in less production, hence less consumption in these years, but after that, the trend told us that oil consumption again increases as production and other factors increase up till 2018. (HDIP 2004, 2019)

In Table 3.2, we can see the descriptive statistics of the variables.

Table 3.2 Descriptive Statistics of Oil variables

	C_{OIL}	R_{OIL}	Pr_{OIL}	I_{OIL}	Pe_{OIL}	GDP_{pc}
Mean	4.4171	727.28	21.551	5.9239	23982	60979
Maximum	8.8000	1498.8	34.490	10.330	80221	247120
Minimum	0.18000	150.31	3.55	2.15	1250	3448.1
Std. Dev.	2.6798	357.69	7.6707	2.1944	26102.	67673
Skewness	0.061248	0.13003	-0.77264	0.13114	0.87698	1.2229
Kurtosis	-1.3461	-1.0735	0.38355	-1.3974	-0.73232	0.32097

3.2.1 Econometric Modeling

The development of the empirical model is based on the law of supply and demand. In Pakistan's context, the theory suggests that an increase in the country's oil reserves, and domestic production would increase the oil supply, which would put downward pressure on the price of oil in the market. This, in turn, would increase the demand for oil as it becomes more affordable for consumers, leading to higher consumption. However, an increase in oil imports would have the opposite effect, as it would increase the supply of oil in the market, putting downward pressure on the price. However, at the same time, it would decrease the demand for domestically produced oil, leading to lower production levels. Therefore, the impact of reserves, prices, imports, and production on oil consumption on Pakistan's energy sector can be analyzed by examining the interplay between supply and demand factors and their effects on oil prices and availability in the market. The relationship between GDP per capita and Oil consumption could be based on Environmental Kuznets Curve Hypothesis. This hypothesis explains that as countries become more developed, they may reach a turning point where oil consumption per capita begins to decline due to increased energy efficiency and the adoption of alternative energy sources. However, the relationship is complex and depends on numerous factors, and empirical evidence is mixed. The following linear model will be used, which is shown in Eq 3.13. The "t" shows the time series property of the variable. The *ln* shows the log transformation of all variables. The log will help in decreasing the fluctuations in data and helps linearize the relationship between them.

$$lnC_{OILt} = \alpha_o + \alpha_1 lnGDP_{pct} + \alpha_2 lnR_{OILt} + \alpha_3 lnPr_{OILt} + \alpha_4 lnI_{OILt} + \alpha_5 lnPe_{OILt} + \varepsilon_t \quad (3.13)$$

To project the consumption of Oil in future, we would first need to check the stationarity of the data and then structural breaks in the data. If the data has breaks, it should be addressed as not considering it would result in spurious regression results. After that, we must check for step or level shifts in the data.

3.2.2. Unit Root test with break

We use the modified Dickey Fuller test with break to find the stationarity of the Data at 5% level of significance with the presence of structural break in the data. C_{OILt} is used for Consumption of Oil, R_{OILt} is Reserves of Oil, Pr_{OILt} is Production of Oil, Pe_{OILt} is Price of Oil, I_{OILt} is import of Oil and GDP_{pct} is GDP per capita. Break year will be shown with the level and first difference. Trend and Break specification is set as 'Intercept only.' Break type is set as innovational outlier.

Table 3.3 Unit Root Analysis with Break

Variables	at level [Break year]	at first difference [Break year]
C_{OILt}	-2.567(-4.44) [1993]	-5.437(-4.44) [2014]
R_{OILt}	-1.466(-4.44) [1989]	-15.441(-4.44) [2019]
Pr_{OILt}	-3.587(-4.44) [1984]	-5.473(-4.44) [1992]
Pe_{OILt}	3.366(-4.44) [2013]	-6.480(-4.44) [2019]
I_{OILt}	0.592(-4.44) [2007]	-4.268(-4.44) [2007]
GDP_{pct}	0.514(-4.85)[2019]	-6.251(-4.85) [1992]

*Significance level is 5% (-4.44 set for intercept only and -4.85 set for intercept and trend only)

The results shown in Table 3.3 show that all six Variables are non-stationary at level and stationary at first difference. In the case of GDP per capita, it shows trend stationary properties with intercept and trend included at first difference.

3.2.3 Using SIS to check for Structural Breaks in Model

We have used the SIS technique to detect multiple structural breaks in the consumption of Oil Series. The target size is set as small or 1% which is selected as standard level for significance and allows at least 1 dummy for breaks present in the data. Table 3.4 shows the significant structural break years, and the figure will show the breaks graphically for researcher to analyze and the possible explanation of the breaks will be mentioned below.

Table 3.4: Step Indicator Saturation Technique

Dependent Variable = C_{OILt}

Break Year	Coefficient	Std. Error	t-value	t-prob
Constant	*0.738164*	*0.1007*	*7.33*	*0.0000*
S1:1984	*-0.488664*	*0.1424*	*-3.43*	*0.0017*
S1:1987	*-0.652343*	*0.1332*	*-4.90*	*0.0000*
S1:1991	*-0.478325*	*0.1332*	*-3.59*	*0.0011*
S1:1993	*-0.538067*	*0.1163*	*-4.63*	*0.0001*
S1:2003	*0.492896*	*0.1163*	*4.24*	*0.0002*
S1:2007	*-0.828519*	*0.1126*	*-7.36*	*0.0000*
S1:2018	*1.29383*	*0.1126*	*11.5*	*0.0000*

R-square = 0.96
Adj.R-sq= 0.95
Sigma=0.174
RSS = 0.973
Log-likelihood = 17.54
No. of Parameters = 8

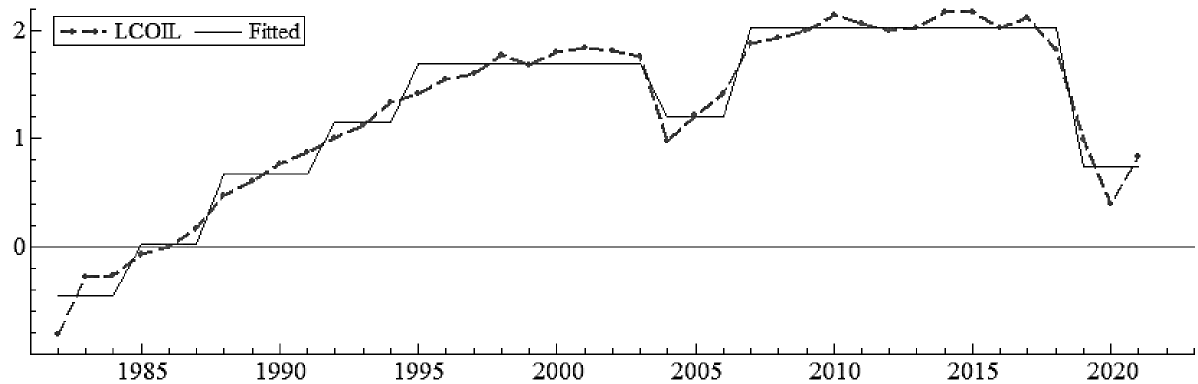


Fig. 3.3: Graphical Presentation of multiple breaks detected using SIS

In the Graph, we can see that multiple breaks are detected in the model. The step shifts in 1984, 1987 1991 and 1993 shows increase in the consumption of oil because of the increase in reserves and local production of Crude oil in the country. An explanation of the break in 2003 was the fall of production and reserves discovered in that year. Moreover, Natural Gas was used as substitute fuel for generating energy in that era. The peak in 2007 was the high rate of consumption of Oil due to high production rate and reserves rate. Also Import of Oil (I_{OILt})

graph also shows upward trend meaning the import also increased in that year. The break in 2018 shows the trend of oil consumption going down as Natural Gas as well as Coal consumption increased in that year and reserves for these two fuels also increased, so these both were used to generate energy in the replacement of Oil. The country was purely dependent on Fossil fuels for energy consumption.

We will keep these step breaks and will regress it with the other independent variables and results will show only significant breaks and variables.

3.2.4 Co-integration Test

To find out the Co-integration among variables of Oil consumption model, we will apply Ordinary Lest Square methodology to find out whether variables are co-integrated or not. The table 3.5 will show only significant variables and breaks.

Table 3.5 Long run estimated Oil Model

Dependent Variable = lnC_{OILt}

	Coefficient	Std. Error	t-value	t-prob
$lnGDP_{pct}$	-0.124766	0.04226	-2.95	0.0056
$lnPr_{OILt}$	0.684435	0.1464	4.68	0.0000
S1:1991	-1.07558	0.1180	-9.11	0.0000
S1:2007	-0.552063	0.1098	-5.03	0.0000
S1:2018	1.21557	0.1675	7.26	0.0000

sigma	= 0.26818	RSS	= 2.517
no. of parameters	= 5	se(COIL)	= 0.808
log-likelihood	= -1.442		
no. of observations	= 40		
mean(COIL)	= 1.259		

The final model after estimating the co-integration relationship can be written as Eq 3.14

$$lnC_{OILt} = (-0.124)lnGDP_{pct} + 0.68Pr_{OILt} + (-1.075(1991_t)) + (-0.552(2007_t)) + 1.21(2018_t) + \varepsilon_t \quad (3.14)$$

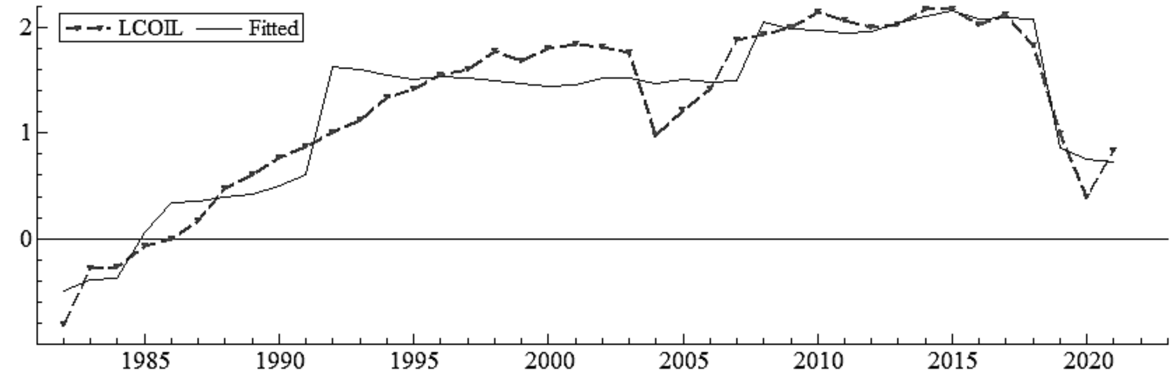


Fig. 3.4: Long run estimation graph of Oil Model

Table 3.6 shows the test summary of the residuals obtained from long run estimated Oil Model

Table 3. 6 Summary of Residual Analysis

AR 1-2 test: F(2,33)	*2.1733 [0.1298]*
ARCH 1-1 test: F(1,38)	*4.4783 [0.0409]**
Normality test: Chi^2(2)	*3.3720 [0.1853]*
Hetero test: F(7,32)	*2.0155 [0.0838]*
Hetero-X test: F(8,31)	*2.4015 [0.0382]**
RESET23 test: F(2,33)	*2.5191 [0.0959]*

In table 3.6, p-value of AR 1-2 test shows value above 5% level of significance, which means we cannot reject null hypothesis at 5% level and conclude that there is no autocorrelation. Hetero and Normality tests also show p-value greater than 5% level of significance. Thus we cannot reject the null hypothesis that there is no heteroscedasticity in dependent variable and series is not normally distributed. The value of ARCH 1-1 test and Hetero-x test shows value above 1% level of significance which concludes that we cannot reject null hypothesis of no heteroscedasticity in the model at 1% level of significance. This table shows that model passes

AR 1-2, Normality and Hetero tests at 5% level whereas ARCH 1-1 test and Hetero-X test show support for the model at 1% level of significance.

In Regression results shown in Table 3.5, GDP per capita shows a negative and significant relationship with the Consumption of Oil. As variables are logged transformed, we will conclude that a 1% increase in GDP per capita of the country decreases 0.12% of Oil consumption in the energy sector. There are a few reasons; one is that as the country's economic growth rises, the shift from oil to gas and coal was seen in the past. The energy sector goes towards more efficient and cheap means of producing Energy in the country. Crude oil is expensive in the international market as well as in the local market, so shifting to cheaper sources becomes inevitable. Another reason is the phenomena of the '*Resource Curse Hypothesis'* The resource curse hypothesis, also known as the "paradox of plenty," is the idea that countries with an abundance of natural resources, such as oil, gas, minerals, or timber, tend to have lower economic growth, higher levels of corruption, and worse development outcomes than countries with fewer natural resources. According to this hypothesis, the presence of natural resources can lead to a number of negative consequences. For example, it can create a dependence on volatile commodity markets, which can lead to economic instability and fluctuations in government revenue. It can also lead to a concentration of wealth and power among a small elite and the neglect of other sectors of the economy. Additionally, natural resource revenues may be used to finance conflict or authoritarian regimes, further contributing to social and political instability. Pakistan has faced the poor infrastructure issue, especially in the energy sector, due to Political Instability. (Asif, Khan et al. 2020). Another study finds out that Fossil Fuel consumption has an inverted U-Shape relationship with the GDP per capita of Pakistan. It means that the relationship is positive in the short run, but it becomes negative in the long run. The author also suggests that Fossil fuel is not a sustainable source of producing

Energy in the long run because of inefficiency and poor infrastructure of the energy sector (Wang, Hassan, et al. 2022).

Production also shows a significant and positive relationship with oil consumption, as more oil production will lead to more oil consumption. An increase of one percent in local oil production resulted in a 0.68 percent increase in oil consumption. More oil production will lead to more consumption as we heavily rely on Furnace Oil for producing Energy, which justifies the positive relationship. These results show that to increase the usage of oil in producing Energy, government must increase its efforts in digging Wells and other measures to find more oil reserves in the country. Similarly, the Production also shows that more oil production can lead to more consumption of oil in the Energy Sector, which suggests that Government would need to establish more furnace oil-powered plants in the future. Significant step breaks were found in 1991, 2007, and 2018. The reason for the breaks is explained while finding the step shifts using the SIS technique.

To find out whether co-integration exists or not, we will check the stationarity of the residuals, which turned out to be IID (Independent and Identically distributed) and statistically significant at a 5% level of significance, showing a value of **-4.507** (-1.94), rejecting the Null hypothesis of Unit root existence in residual series which means that the variables are co-integrated.

3.2.5 Parameter Stability Test

We will use the forecast Chow-test to check for the parameter stability after running the co-integration test using OLS. We have already added step-indicators in the regression equation The graph shows the 1-step chow-test at p-value = 1%

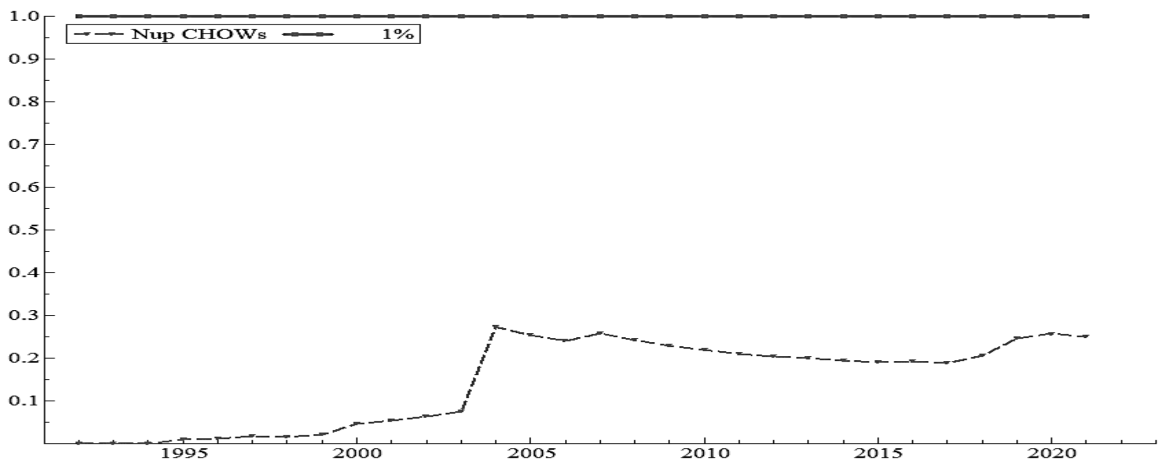


Fig. 3.5: Chow test for Parameter Stability (C_{OILt})

In Fig 3.5, we can see that there is no prominent structural break in the model and thus we can conclude that parameters are stable, and we can now check for the presence of Error correction mechanism in the model

3.2.6 Error Correction Model

We have checked the Error Correction mechanism by taking the lag of residual obtained from co-integration test (ECT), apply differencing on the log transformed series of GDP per capita ($DLGDP_{pct}$) and Production of Oil(DLPr_{OILt}) and regress it on Differenced series of Consumption of Oil(DLC_{OILt}). The results can be seen in Table 3.7

Table 3.7 Short Run analysis of Oil Model

Dependent Variable = DC_{OILt}

	Coefficients	**Std. Error**	**t-value**	**t-prob**
Constant	*-0.0835709*	*0.1003*	*-0.833*	*0.4105*
$DLGDP_{pct}$	*0.855819*	*0.8163*	*1.05*	*0.3016*
$DLPr_{OILt}$	*0.659516*	*0.3127*	*2.11*	*0.0422*
ECT_1	*-0.350380*	*0.1646*	*-2.13*	*0.0404*

R-square = 0.202
Adj. R-square = 0.134
RSS = 2.36653023
Log-likelihood = -0.696935
No. of observations = 39
No. of parameters = 4

The Error correction terms came to be negative and significant (co-efficient = -0.35, t-prob = 0.04) which shows the Error Correction Mechanism will help in stabilizing the disequilibrium in the model and time required to achieve equilibrium will be $\frac{1}{-0.35} = 2.85$

3.2.7 Forecasting

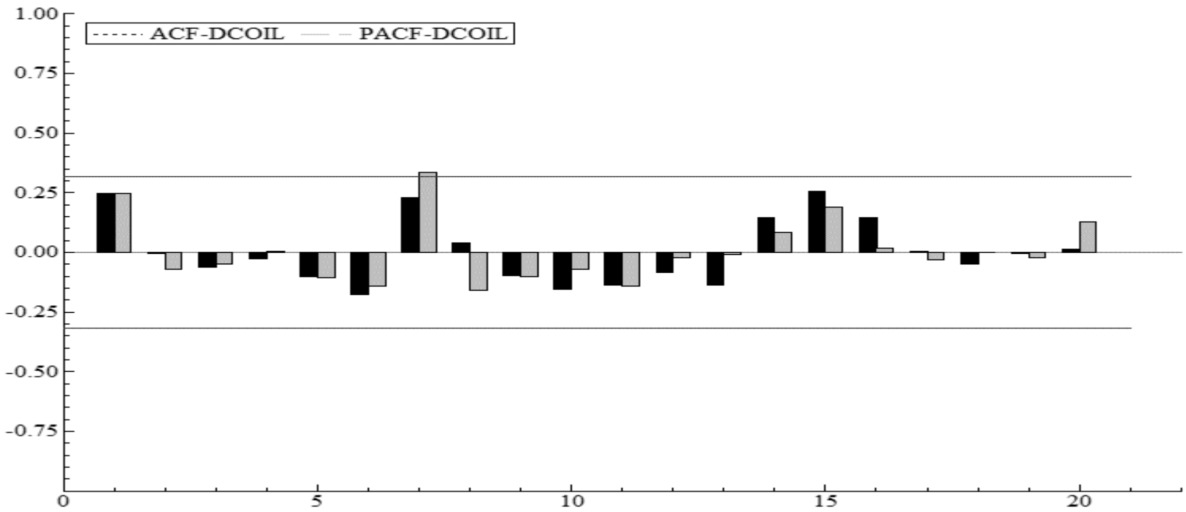


Fig. 3.6: ACF and PACF Plot of DC_{OILt}

Now using ARFIMA function, we will project the future consumption of Oil in Energy sector of Pakistan using lag values of same series. We will let the d be '1' as series becomes stationary after taking first difference. To find 'p' and 'q' of series, we will plot the ACF and PACF respectively.

In this Fig 3.6 we can see that AR peaks in PACF (grey ones) are not significant up till 6th lag showing that the AR value can be taken as 1, 6 and other values while running ARFIMA analysis. The MA peaks (black ones) in ACF plot have not shown any significant lag which meant that different combinations of MA could be taken e.g. 1,2,3 and so on. The diagnostic check will finally tell us which model is the best.

As breaks are present in the data, we will forecast the Oil consumption series with the inclusion of Impulse dummies in the data. The final ARFIMA-B model with breaks is shown below. (B is used for dummy variables adjusted for structural breaks in the series)

Table 3.8: ARFIMA-B Projection Results of Oil consumption (6,1,4)

Dependent Variable = $\boldsymbol{DC_{OILt}}$

	Coefficient	Std. Error	t-value	t-prob
AR-6	*-0.741449*	*0.1395*	*-5.31*	*0.000*
MA-2	*-0.774283*	*0.2078*	*-3.73*	*0.001*
MA-3	*-0.531869*	*0.2813*	*-1.89*	*0.068*
MA-4	*0.545188*	*0.2314*	*2.36*	*0.025*
Constant	*0.314651*	*0.01050*	*30.0*	*0.000*
I:2004	*-3.16010*	*0.2020*	*-15.6*	*0.000*
I:2007	*1.58467*	*0.1984*	*7.99*	*0.000*
I:2018	*-3.82058*	*0.2267*	*-16.9*	*0.000*
I:2019	*-4.23694*	*0.2313*	*-18.3*	*0.000*

log-likelihood	= -14.7187254		
no. of observations	= 40	no. of parameters	= 10
AIC.T	= 49.4374509	AIC	= 1.23593627
mean(DCOIL)	= 0.053	var(DCOIL)	= 1.1514
sigma	= 0.268641	sigma^2	= 0.0721677

Different AR and MA combinations have been tried. While a high number of AR and MA terms were showing good in-sample forecast but using them will cause the issue of degree of freedom. Keeping the parsimonious model in mind, impulse dummies have also been used with AR and MA parameters to get the best possible in sample forecast. We have seen in the table that Impulse dummies show significant values while forecasting the Oil series, proving the presence of structural break. This model is also proved to be best parsimonious model while comparing the values of AIC, SC and HQ. This model shows the AIC value of 1.2359, SC value of 1.6582 and HQ value of 1.3886. All three criterions tell us that the best model of projecting Oil consumption is ARFIMA-B (6,1,4). Meanwhile lags of AR (1,2,3,4,5) and MA (1) shows insignificant values which helps us in fixing these lag terms and getting the best model. Below are the descriptive statistics of residuals obtained from ARFIMA-B results. This includes the test for normality, ARCH 1-1 test and Portmanteau Chi-square test.

Table 3. 9 Descriptive Statistics of Residuals

Normality test: Chi^2(2)	*4.5265 [0.1040]*
ARCH 1-1 test: F(1,29)	*0.016480 [0.8987]*
Portmanteau(6): Chi^2(2)	*4.5612 [0.1022]*

The model shows no Normality issue, no Autocorrelation and is the best parsimonious model for forecasting the time series. Next step is to forecast the differenced time series and obtain actual values by re-integrating the forecasted series with 1. The forecasting can be seen below with Standard Error set to ± 2.

Furthermore, we will plot the residuals ACF as shown in fig 3.7 to check if any lag is crossing specified significance level which will tells us that model is not appropriate for forecasting.

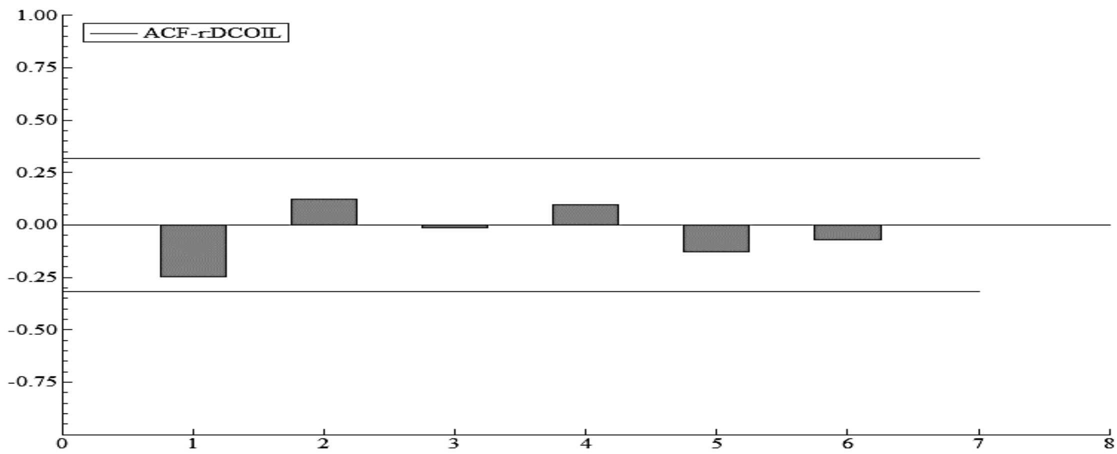


Fig.3. 7 ACF plot of Residuals

As we can see that no lag of residuals has crossed significance level so we can say that the residual analysis supports the usage of ARFIMA-B (6,1,4) model for projections

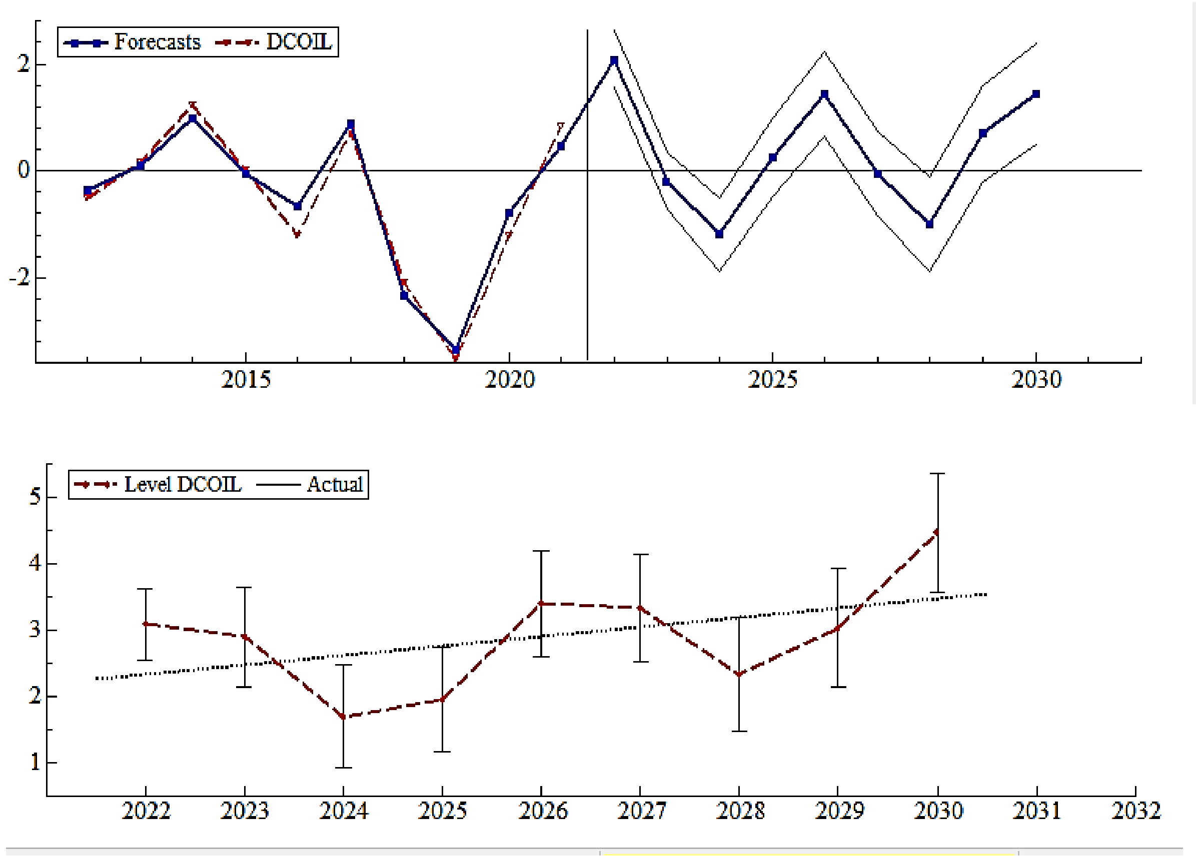


Fig. 3.8: ARFIMA-B Projections of Oil Consumption (6,1,4)

In this Fig 3.8, we can see that before 2020, the consumption was going down because of the use of substitute fuels such as Natural gas and coal, but after 2021, the linear line is drawn to show that consumption rose, showing the increased use of furnace oil in the power sector to meet the energy demand of the country. Our projections of future consumption of oil start going downward, showing a decrease in consumption of -6%. The rate of increase in Usage of Oil would also increase to 47 percent in next years. In 2026, the consumption of Oil in the energy sector will be 3.39 MTOE, and in 2030, the consumption value will be 4.46 MTOE. The final growth rate of consumption at the end of 2030 will be 44 percent. The major reason could be that Pakistan's energy sector still relies very much on Crude Oil to produce energy as our infrastructure is not yet established much for renewable energy sources. The IPPs which are producing energy in Pakistan use Furnace oil, and thus, they supply expensive energy, but the government has no option. That is why Government will not decrease the usage of Oil for energy production in the coming years. After 2025, the upward trend tells us that due to the lack of better infrastructure for Renewable Energy in Pakistan, the oil will be consumed again in great quantity as the energy crisis will remain a major problem so the government will fulfill the demand by using crude oil as well. The issue of energy prices and substitute fossil fuel supplies would also remain a problem for energy production, and thus, the country will be bound to use Furnace Oil to produce energy. This Projection is also supported by the Pakistan Economic Survey Report, Energy chapter (2020-2021), which states the consumption of petroleum products increased in different sectors from 12.5 million Tons to 14.7 million Tons during the given time period. Overall, the results suggested that IPPs will remain a major part of energy production, and the government will give licenses to more oil-powered plants to produce energy as Government sees this as an effortless way of producing energy despite the huge cost of it.

3.3 GAS

The Graphical Presentation of the variables can be seen in Fig. 3.9. The C_{GASt} is measured in MTOE (Million Tons of Oil Equivalent), R_{GASt} is Reserves of Gas in Tcf (Trillion Cubic Feet), $P_{GASt}$is production of Gas which also in Tcf, $I_{LPGt}$is Import of LPG in Mt(Million Tones), $Pe_{GASt}$is Price of Gas for Energy sector and is measured in Rs/Thousand Cft, and GDP_{pct} is GDP per capita in Current LCU Rs. Import of LPG data is only available from 1993, so we will estimate the equation based on the data from 1993-2021.

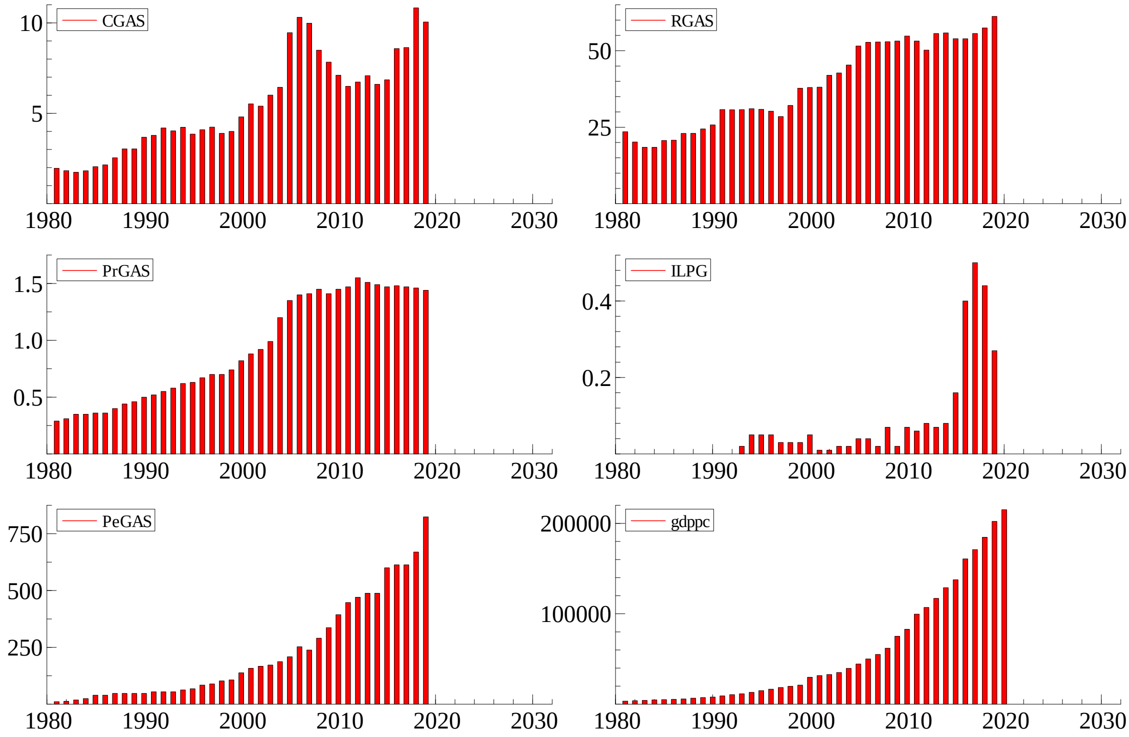


Fig. 3.9: Graphical representation of Gas Model

In Fig 3.9, we can see that the Trend in Consumption of Gas(C_{GASt}) shows upward direction in 2004, which was the result of government decision to shift from Oil to Gas in Producing Energy because it was cheaper and also Transport sector specially commercial vehicles were also converted majorly on Gas. The afterward decrease and increase show up and down moment because of less production and reserves found at respective time.

Table 3. 10 Descriptive Statistics of Variables of Gas Model

	C_{GASt}	R_{GASt}	Pr_{GASt}	I_{LPGt}	Pe_{GASt}	GDP_{pct}
Mean	5.6193	40.177	0.94463	0.11759	254.90	60979
Maximum	10.830	63.310	1.5500	0.50000	857.00	247120
Minimum	1.7400	18.440	0.29000	0.010000	10.960	3448.1
Std. Dev.	2.6707	14.254	0.45177	0.14957	252.20	67673
Skewness	0.26635	-0.0200	-0.007510	1.6556	1.0170	1.2229
Kurtosis	-1.0919	-1.4805	-1.6646	1.2500	-0.2101	0.32097

3.3.1 Econometric modeling

The empirical model based on the relationship between the consumption and different mentioned factors is developed based on theory of supply and demand. According to this theory, the consumption of gas in the energy sector of Pakistan is influenced by the interaction of supply and demand factors. The availability of gas reserves, the level of gas production, and the cost of gas imports can influence the quantity of gas supplied to the power plants to produce energy. Overall, the theory of supply and demand provides a framework for understanding the complex interplay between the factors that influence gas consumption, reserves, imports, production, and prices in the energy sector of Pakistan. By analyzing these factors, policymakers can develop strategies to ensure a reliable and affordable supply of gas for the country's energy needs.

The following linear model is being used to estimate the regression shown in Eq 3.15

$$C_{GASt} = \beta_o + \beta_1 GDP_{pct} + \beta_2 R_{GASt} + \beta_3 Pr_{GASt} + \beta_4 I_{LPGt} + \beta_5 Pe_{GASt} + \varepsilon_t \qquad (3.15)$$

For Time series analysis, it is necessary condition for series to be firstly checked for presence of unit root in the presence of break and then structural breaks.

3.3.2. Unit Root test with Break

The Variables will be checked for stationarity by using modified dickey fuller test which allows for single break in the data. This is a necessary condition when choosing co-integration test and specially forecasting, which will give spurious or in-accurate results if the series is non-stationary or I(1) . Break year will be shown with the level and first difference. Trend and Break specification is set as 'Intercept only.' Break type is set as innovational outlier.

Table 3.11 Unit Root Analysis-ADF of Gas Model

Variables	**at level[Break Year]**	**at first difference[Break Year]**
C_{GASt}	-3.013(-4.44)[2002]	-6.197(-4.44)[2005]
R_{GASt}	-2.229(-4.44)[1997]	-6.382(-4.44)[2005]
Pr_{GASt}	-2.994(-4.44)[1999]	-4.847(-4.44)[2004]
Pe_{GASt}	1.869(-4.44)[2017]	-6.343(-4.44)[2009]
I_{LPGt}	-2.701(4.44)[2020]	-7.755(-4.44)[2012]
GDP_{pct}	-3.551(-4.85)[2020]	-9.749(-4.85)[2015]

*Significance level is 5%(-4.44 for no intercept and no time trend & -4.85 for both intercept and time trend)

In Table 3.11, all variables are non-stationary at level with 5% level of significance, then after differencing, all six series became stationary except GDP per capita which have shown trend stationary properties at first difference.

3.3.3 Using SIS to check for Structural Breaks in Model

The Step Indicator Saturation technique is used to detect outliers and Multiple Breaks in the data. We check the series by running regression for outlier and break detection. The Target size is set as 0.01 or 1% means at least one dummy would be incorporated in the model to check for breaks. The results can be seen in Table 3.12.

Table 3.12 Step Indicator Saturation Technique

Dependent Variable = C_{GASt}

Break Year	Coefficient	Std. Error	t-value	t-prob
Constant	*8.53000*	*0.2303*	*37.0*	*0.0000*
S1:1987	*-1.01714*	*0.2612*	*-3.89*	*0.0005*
S1:1989	*-1.04091*	*0.2504*	*-4.16*	*0.0002*
S1:2000	*-1.77159*	*0.1902*	*-9.31*	*0.0000*
S1:2004	*-4.07417*	*0.2488*	*-16.4*	*0.0000*
S1:2007	*1.75667*	*0.2974*	*5.91*	*0.0000*
S1:2009	*1.35000*	*0.2660*	*5.08*	*0.0000*
S1:2015	*-1.80000*	*0.2660*	*-6.77*	*0.0000*
S1:2017	*-1.83000*	*0.3257*	*-5.62*	*0.0000*
S1:2019	*1.91000*	*0.3257*	*5.86*	*0.0000*

R^2	=	0.988753
Adj.R^2	=	0.985488
log-likelihood	=	-6.45631
RSS	=	3.28917543
No. of parameters	=	10
sigma	=	0.325734

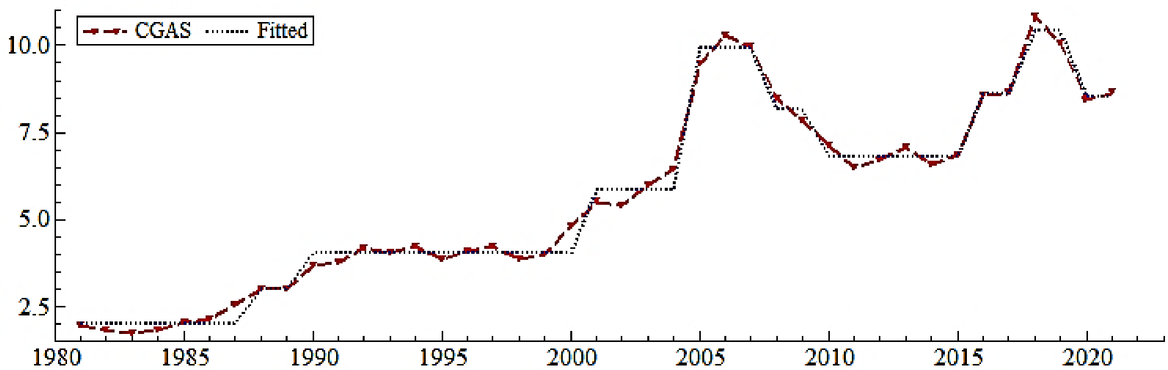


Fig. 3.10: Breaks detected using SIS technique

Multiple structural breaks are detected in different years. In 2004, the government used Natural Gas as a substitute for Oil to produce Energy, and thus, in the same year, Oil consumption started falling because of less production and a decrease in imports. Gas consumption also goes abruptly high in the transport sector; CNG was also introduced for Cars and commercial vehicles as the government's main attention turned towards Gas for several reasons, including cheaper energy and fewer supplies issues. Then in 2007-08, the break shows the fall in gas consumption in the energy sector due to the availability of other sources such as Oil and Coal to produce Energy. The continuously increasing demand for Energy was becoming challenging for Gas power plants to fulfill, so the government used Oil and Coal that year to fulfill the country's demand. The breaks in 2015 and 2017 show the increased rate of consumption of Gas as Gas power plant infrastructure was more developed than previous years, and reserves were increasing as well as production. The last break in 2020 shows the decline in the usage of Gas in producing Energy, and Oil usage was also lessened because the government used Coal as a major source in that year (which could also be seen in the Coal consumption graph), which was cheaper. Pakistan has an abundant amount of reserves of it. It was also beneficial that the import bill of the other two fossil fuels would be less, and the government's burden could be lessened.

3.3.4 Co-Integration Test

Firstly, we will apply a Co-integration test to find out whether the variables are co-integrated or not with breaks included. To do that, we use the OLS methodology to estimate the co-efficients. The regression results can be seen in Table 3.13.

Table 3.13. Long run Estimated Gas Model

Dependent Variable = C_{GASt}

	Coefficient	Std. Error	t-value	t-prob
Pr_{GASt}	*4.96415*	*0.2941*	*16.9*	*0.0000*
$ILPG_{GASt}$	*4.87314*	*0.5870*	*8.30*	*0.0000*
S1:2004	*-2.25857*	*0.2679*	*-8.43*	*0.0000*
S1:2007	*2.02863*	*0.2903*	*6.99*	*0.0000*
S1:2009	*1.82492*	*0.2604*	*7.01*	*0.0000*
S1:2017	*-2.27259*	*0.2353*	*-9.66*	*0.0000*
S1:2020	*1.28963*	*0.3766*	*3.42*	*0.0025*

sigma	=0.317846	RSS	= 2.12154375
log-likelihood	=-3.60943		
no. of observations	=28	no. of parameters =	7
mean(CGAS)	=6.94857	se(CGAS)	= 2.16331

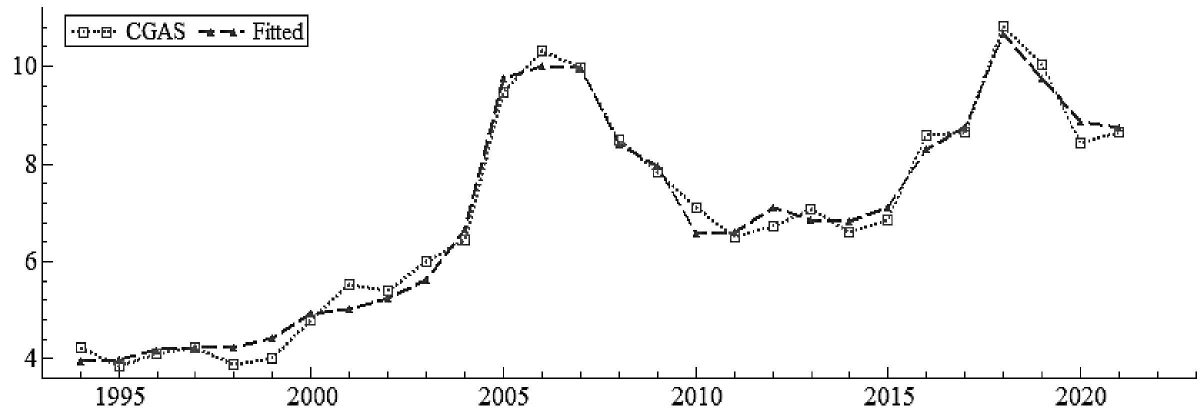


Fig. 3.11: Long run estimation of Gas Model

Final estimated model can be written as Eq 3.16

$$C_{GASt} = 4.964Pr_{GASt} + 4.873ILPG_{GASt} - 2.258(2004_t) + 2.028(2007_t) - 1.824(2009_t) + (-2.272(2017_t)) + 1.289(2020_t) + \varepsilon_t \quad (3.16)$$

The test summary of the residuals obtained from long run estimation results can be seen in table

Table 3. 14 Summary of Residuals

AR 1-2 test: F(2,19)	*0.73192 [0.4941]*
ARCH 1-1 test: F(1,26)	*2.3230 [0.1395]*
Normality test: Chi^2(2)	*1.5852 [0.4527]*
Hetero test: F(9,18)	*0.93926 [0.5164]*
Hetero-X test: F(10,17)	*0.90584 [0.5486]*
RESET23 test: F(2,19)	*1.0110 [0.3826]*

In Table 3.14, we can see the analysis of residuals which are extracted from the co-integration test. The null hypothesis of AR 1-2 test is no autocorrelation, and the value is above 5% level of significance which means we cannot reject null hypothesis and confirm that there is no autocorrelation in the model. The ARCH 1-1 test has null hypothesis of no heteroscedasticity and our value is above 5% level of significance, showing that we cannot reject null hypothesis and conclude that there is no heteroscedasticity in model. Normality test also accepts the null hypothesis and shows that residuals are stationary. Similarly, Hetero and Hetero-X test also accepts the null hypothesis of no hetero issue in the dependent as well as independent variable. RESET23 test has null hypothesis of no specification biased and our value suggested us that we accept the null hypothesis and there is no issue of model specification.

Fig.3.11 shows us the graphical presentation of the results. In the Regression Analysis, we use the auto metrics function of OxMetrics 7, which helps us in removing the insignificant variables and breaks from the results. In this regression result, Production of Gas(Pr_{GASt}) shows significant and positive impact on Consumption of Coal. The co-efficient is 4.96 which shows that a 1-unit increase in the production of Natural Gas will increase the Consumption of Gas by 4.96 units. As our energy sector is mostly on fossil fuel, we need more production of gas to fulfil energy demand. Import $ILPG_{GASt}$ also shows significant and positive behavior with Consumption of Gas. The co-efficient is 4.87 which means that a 1-unit increase in import of Gas will increase Consumption of Gas by 4.87 units. This is also due to the dependence of Energy sector on Fossil Fuel so more import of LPG or LNG in the country would result in more consumption in Energy. Different step breaks in 2004, 2007, 2009, 2017 and 2020 shows significance after co-integration analysis. The reason behind these breaks is already discussed in SIS heading

Next step is to check the stationarity of Residuals obtained from OLS regression. The Augmented Dickey Fuller Test is used to check it. After checking, the t-stat value turns out to be **-5.51** which is less than t-critical value of **-1.94**, neglecting that there is unit root present and therefore we can conclude that residuals are IID which means that these are Independently and Identically distributed values and this result shows that variables are co-integrated.

3.3.4 Parameter Stability Test

After checking co-integration, we will check whether the Parameters are stable after incorporating structural breaks or not. So we will run the forecast chow test with p-value = 1%

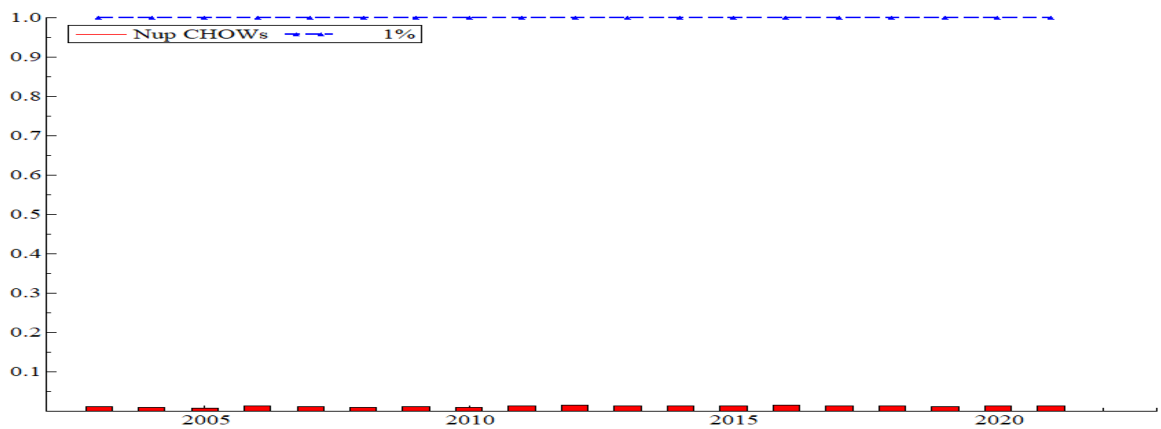


Fig. 3.12: Parameter stability test

The peaks are under 1% of chow test p-value and we can say that parameters are stable after including multiple breaks in the dependent variable and there no structural break present in the model

3.3.5 Error Correction Model

To find whether Error correction mechanism holds or not, we will run short run analysis. We will take lag of residual obtained from running co-integration test and take Difference of Pr_{GASt}(Production of Gas) and $ILPG_{pct}$ (Import of LPG) as these were the only variables which were significant in long run analysis along with multiple breaks. The ECT is the residual lag term which tells us whether the disequilibrium will balance itself or not in the short run. The Error correction term came out to be negative and significant (coefficient= **-1.397**, t-stat=0.0197) which shows the Error correction mechanism hold in this case and time required to balance itself will be $\frac{1}{-1.397} = 0.71$

Table 3.15 Short Run analysis of Oil Model

Dependent Variable = DC_{GASt}

	Coefficient	Std. Error	t-value	t-prob
Constant	*-0.0283512*	*0.1665*	*-0.170*	*0.8662*
DPr_{OILt}	*7.07379*	*2.442*	*2.90*	*0.0079*
DI_{LPGt}	*1.08941*	*1.933*	*0.564*	*0.5783*
ECT_1	*-1.39758*	*0.5593*	*-2.50*	*0.0197*

R-square	= 0.418	sigma=0.800
Adj. R-square	= 0.346	
RSS	= 15.379	
Log-likelihood	= -31.34	
No. of observations	= 28	

3.3.6 Forecasting

To get the optimal value of ‘p’ and ‘q’ for the model, we will check the PACF and ACF plot of C_{GASt} and would pick optimum value on which the model would give better projections

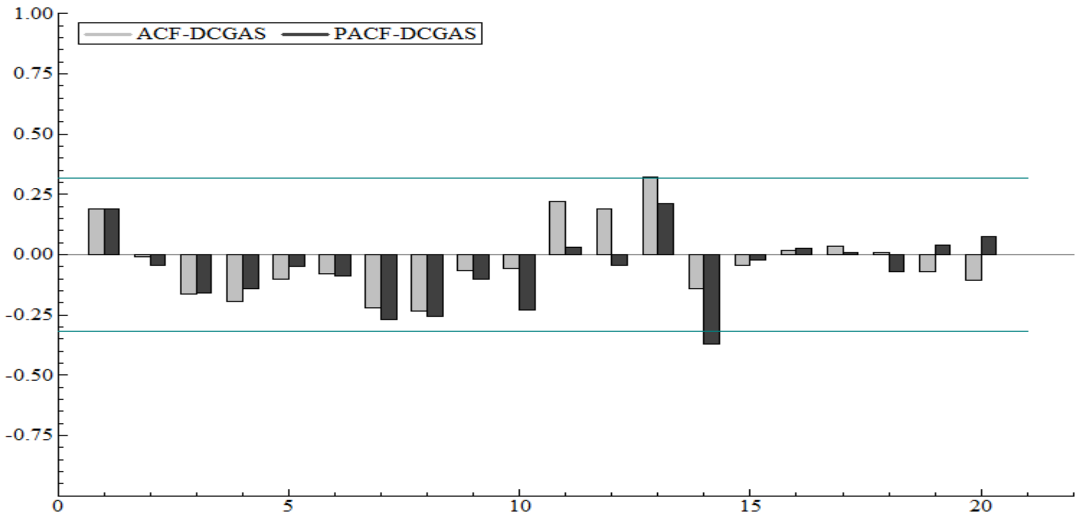


Fig. 3.13: PACF and ACF plot of $\boldsymbol{DC_{GASt}}$

The series was non-stationary so to use ARFIMA-B modeling, we applied the first difference and it became stationary so the order of d in this case would be 1. By looking at the plot, we can see that significant lags of AR and MA are on 14^{th} and 15^{th} lag, respectively. Using all those lags will result in over parameterized model and the degree of freedom would be much less and parsimony property would be neglected. So we will use the Impulse Indicator Saturation Technique to check for impulse breaks and then significant breaks will be included to improve the forecasting. If the higher lags need to be taken for projections, then we will fix the insignificant lags of AR and MA to lessen the parameters.

Table 3.16 ARFIMA-B Projection Results of Gas Model-(12,1,8)

Dependent Variable = $\boldsymbol{DC_{GASt}}$

	Coefficient	**Std. Error**	**t-value**	**t-prob**
AR-11	*-0.498492*	*0.1477*	*-3.38*	*0.002*
AR-12	*0.415067*	*0.1414*	*2.94*	*0.007*
MA-8	*-0.448383*	*0.2222*	*-2.02*	*0.054*
Constant	*0.138377*	*0.02987*	*4.63*	*0.000*
I:2001	*0.650289*	*0.2144*	*3.03*	*0.005*
I:2005	*2.97573*	*0.2193*	*13.6*	*0.000*
I:2008	*-1.82105*	*0.2277*	*-8.00*	*0.000*
I:2009	*-0.901430*	*0.2339*	*-3.85*	*0.001*
I:2010	*-0.831949*	*0.2318*	*-3.59*	*0.001*
I:2016	*1.58507*	*0.2812*	*5.64*	*0.000*
I:2018	*1.50409*	*0.2623*	*5.73*	*0.000*
I:2020	*-1.86180*	*0.2842*	*-6.55*	*0.000*

log-likelihood	= -4.8785423		
no. of observations	= 40	no. of parameters	= 13
AIC.T	= 35.7570846	AIC	= 0.893927115
mean(DCGAS)	= 0.167	var(DCGAS)	= 0.680391
sigma	= 0.241956	sigma^2	= 0.0585425

Different AR and MA lags were being checked to obtain the future projections. The Breaks which show significant p-values are included and the most appropriate model came to be ARFIMA-B (12,1,8) including Breaks at different intervals. This model is selected based on the minimum values of AIC 0.8393, HQ 1.0924 and SC 1.4428. The three criterions show us the suitable parsimonious model for forecasting although the parameters number are bit high because of many breaks present in the data and degree of freedom value got little less.

After that, we will check the descriptive statistics of the residuals obtained from the model as shown in table 3.17. The three tests passed the model in normality, Autocorrelation and degree of freedom test.

Table 3. 17 Descriptive Statistics of Residuals

Normality test: Chi^2(2)	*3.5259 [0.1715]*
ARCH 1-1 test: F(1,26)	*0.56276 [0.4599]*
Portmanteau(6): Chi^2(3)	*5.7197 [0.1261]*

After that, we will plot the ACF of Residuals to see whether any lag of residuals is showing significance or not. This will further help us in finding the authenticity of the model.

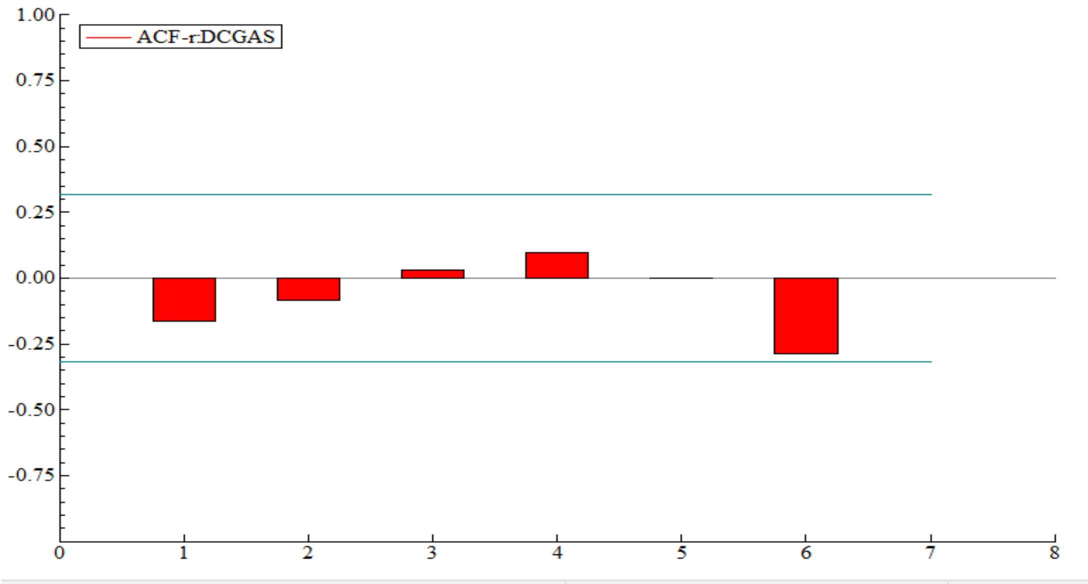


Fig.3. 14 ACF plot of Residuals

Fig 3.14 shows us that although, 6th lag is showing a peak, it is still in the significance level and thus we can conclude that residuals obtained from the model give us go-ahead with projections.

Below is the Fig 3.15, which shows us the final forecasting results of Gas consumption in coming years from 2022 to 2030.

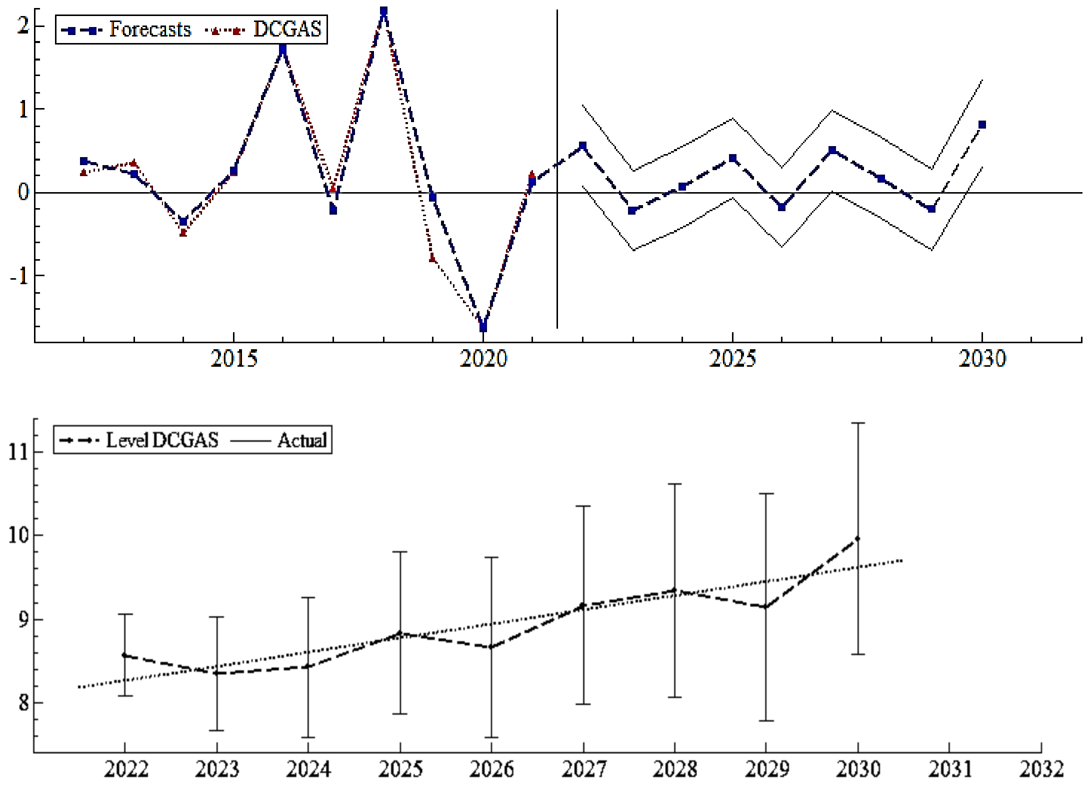


Fig. 3.15: ARIMA-B(12,1,8) Projections of Gas model

The Projection results in Fig 3.15 tells us that after 2021, the consumption is going downward a bit which gave us the idea that government will starts decreasing the consumption of Natural Gas for energy production in the short run but the overall line drawn shows us that Usage of Natural Gas will increase till 2030. The consumption will be 8.62 MTOE in 2022, 8.85 MTOE in 2025 and approx. 9.81 MTOE in 2030. The projections show us that Natural Gas usage will increase in the coming years up till 2030. There could be an explanation that Gas was being used as a major source of producing energy in the past and to meet the future the energy demand in the country, the government will either made more gas power plants or increase supply of Gas to produce Energy. Our Renewable sector is still yet to be developed, so this result supports the idea that shifting to renewable energy sources in coming years will not be possible and Oil and Gas will be used to meet the energy demand of the country.

3.4 COAL

The unit to measure Consumption of Coal (C_{COALt}) is MTOE, Reserves of Coal (R_{COALt}) is in Million Tones, Production of Coal (Pr_{COALt}) is also in Million Tones, import (I_{COALt}) is also in Million tones and Price of Coal(Pe_{COALt}) is taken as average of every mine Price divided by Ton and measured as Rs/Ton and GDP per capita(GDP_{pct}) is taken in Current LCU Rs.

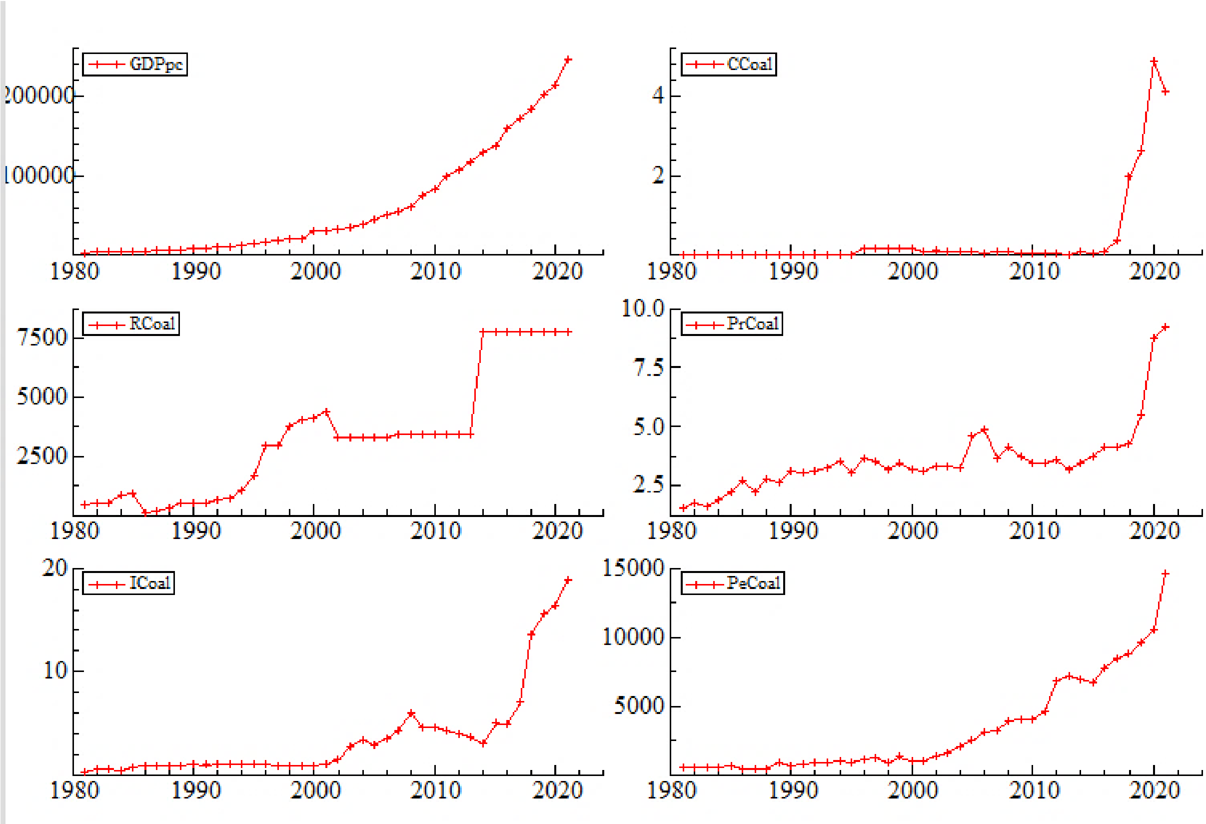


Fig. 3.16: Graphical Presentation of Coal Model

The trend for Coal consumption can be seen in fig 3.16 which shows abrupt increase after 2016, which could relate to the increased quantity of reserves and production of Coal at that time. As already discussed, the Energy sector has faced Oil shortage and to fulfil the demand, Government uses high amount of Bituminous Coal by local production and import and the trend further suggest that government increased the consumption with time. According to International Energy Agency (2021), the fall in consumption of Coal after 2020 for energy production is mainly due to the country's unaffordability of bearing seaborne imports which left the country with one choice, that is to rely on imports by land from Afghanistan and supplies from local mines of the Country. The increase in prices of coal in global market is also said to be a principal factor in consumption downfall in 2021. The major trends in Production, Import Reserves could reflect the change in consumption of coal. Coal is cheaper to use than any other fossil fuel and according to United States Energy department, the average efficiency of Coal Based power plant is 33%.

The following table 3.18 shows the descriptive statistics of the Coal Model variables. The total observations for each variable are 41.

Table 3.18 Descriptive Statistics of Coal Model

Variable	C_{COALt}	R_{COALt}	Pr_{COALt}	I_{COALt}	Pe_{COALt}	GDP_{pc}
Mean	*0.39427*	*3278.4*	*3.5711*	*3.6237*	*3300.2*	*60979*
Maximum	*4.8750*	*7775.5*	*9.2300*	*18.850*	*14646.*	*247120*
Minimum	*0.001*	*102.00*	*1.5800*	*0.31000*	*438.50*	*3448.1*
Std. Dev.	*1.0555*	*2576.9*	*1.4677*	*4.5056*	*3475.8*	*67673*
Skewness	*3.2296*	*0.62012*	*2.2838*	*2.1337*	*1.3574*	*1.2229*
Kurtosis	*9.3548*	*-0.73572*	*6.5235*	*3.7139*	*1.1052*	*0.32097*

The main dependent variable i.e. Consumption of Coal(C_{COALt}) is showing abrupt increase in 2017 till 2020, showing the major replacement of oil and gas with Coal, as for Oil and gas, the consumption goes downward because of less production and other factors. And also growth rate of Reserves (R_{COALt}), Import(I_{COALt}) and Production(Pr_{COALt}) shows similar trends, confirming the fact that the increase in these variables results in increased consumption of coal in the energy sector of the country.

3.4.1 Econometric Modeling

The empirical model developed based on law of supply and demand. As the law suggests, if price of coal gets high, the supply will get high, but the demand will get low excluding other factors etc. In our empirical model, we have tried to find the different determinants which affected the Coal demand in the energy sector. Law of supply could suggest us that as production, import and reserves will go high, the supply of coal to energy sector will also go high owning to the fact that Country has now more coal to produce energy. The law of demand could suggest to us that as price of coal will go high, the demand will eventually go down as country will try to shift to other substitute fuel or sources for producing energy. Relationship between GDP per capita and Consumption of coal would be analyzed based on 'Resource Curse Theory.' The basic model for OLS regression is shown in Eq 3.17.

$$lnC_{COALt} = \gamma_o + \gamma_1 GDP_{pct} + \gamma_2 R_{COALt} + \gamma_3 Pr_{COALt} + \gamma_4 I_{COALt} + \gamma_5 Pe_{COALt} + \varepsilon_t \qquad (3.17)$$

The data of consumption of coal has high values at the end showing structural breaks which is also confirmed by using SIS and IIS technique. For co-integration analysis, we will use the log transformed Consumption variable of coal which would help us in reducing impact of extreme values at the end on overall data, it will also help us in linearizing the relationship between dependent and independent variables. First step of Analysis is to check for unit root in the data by using modified dickey fuller test with break by Perron and Vogelsang (1992). Next step is to check for step shifts in the dependent variable by using Step Indicator Saturation Technique. Then, we will use the Engle-Granger co-integration analysis to check the relationship between dependent and independent variables. If co-integration exists, then we will check Error correction mechanism in the model. For parameter stability, we will use Chow test and finally for projections, we will use ARFIMA-B model.

3.4.2 Unit Root test with Break

The Variables will be checked for stationarity by using modified dickey fuller test which allows for single break in the data. This is a necessary condition when choosing co-integration test and specially forecasting, which will give spurious or in-accurate results if the series is non-stationary or I(1) . Break year will be shown with the level and first difference. Trend and Break specification is set as 'Intercept only.' Break type is set as innovational outlier. Results can be seen in Table 3.19

Table 3.19 Unit Root test with break

Variables	**at level[Break Year]**	**at first difference[Break Year]**
C_{COALt}	-10.528(-4.44)[2017]	-28.355(-4.44)[2017]
lnC_{COALt}	-2.816(-4.44)[2016]	-11.364(-4.44)[2018]
R_{COALt}	-3.096(-4.44)[2013]	-12.195(-4.44)[2014]
Pr_{COALt}	-3.704(-4.44)[2019]	-8.707(-4.44)[2018]
I_{COALt}	-2.198(-4.44)[2017]	-11.247(-4.44)[2007]
Pe_{COALt}	1.523(-4.44)[2016]	-4.657(-4.44)[2020]
GDP_{pct}	0.514(-4.85)[2019]	-6.251(-4.85)[1992]

*Significance level is set at 5%(-4.44 for no intercept and no time trend & -4.85 for both intercept and time trend)

The results suggested us that C_{COALt} is stationary at level, meanwhile GDP per capita shows trend stationary properties and other four variables shows non stationarity at level and stationary at first difference

3.4.3 Using SIS to check for Structural Breaks in Model

The technique used is called Step Indicator Saturation Technique which is commonly used to check for breaks, level shifts and Outlier detection in the data. The target size or Level of significance would be Small(0.01 or 1%) which meant that atleast one dummy would be generated against years in which there could be breaks in the series. Table 3.20 shows us the step shifts or breaks found in the original series.

Table 3.20 Step Indicator Saturation Technique

Dependent Variable = lnC_{COALt}

Break Year	Coefficient	Std. Error	t-value	t-prob
Constant	*1.16427*	*0.3226*	*3.61*	*0.0009*
S1:1995	*-2.08050*	*0.2206*	*-9.43*	*0.0000*
S1:2017	*-3.58342*	*0.3507*	*-10.2*	*0.0000*

sigma =	0.645188	RSS =	15.401885
R^2 =	0.873644	F(2,37) =	127.9 [0.000]**
Adj.R^2 =	0.866814	log-likelihood =	-37.6698
no. of observations =	40	no. of parameters =	3
mean(LCCoal) =	-2.78897	se(LCCoal) =	1.7679

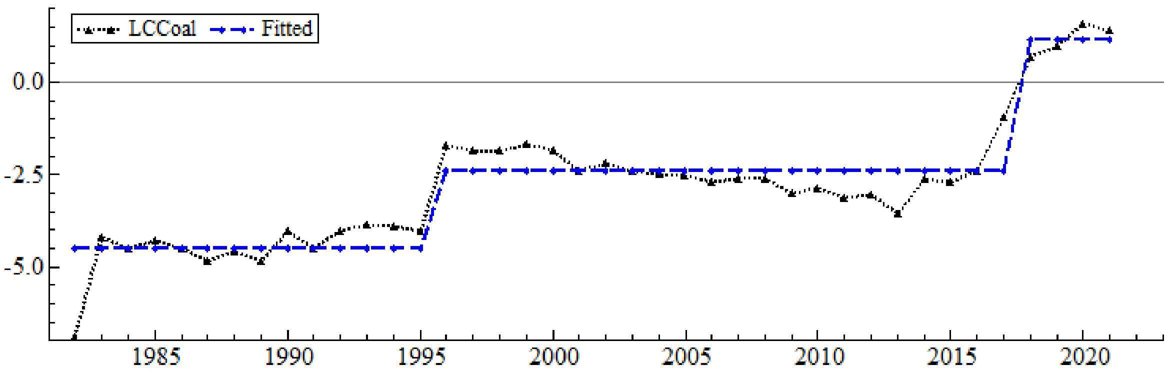


Fig. 3.17: Breaks Detected using SIS

The Break in 1995 in the graph shows the increase in consumption of coal in energy sector which was the result of increase in reserves of coal in that year. The second break is detected in 2017 shows the increase in consumption due to increase in the production and import of the coal during this year. Also reserves were present in high quantity, this also explains the shift in the consumption of coal in energy sector of Pakistan in that year.

3.4.4 Co-integration Test

First, to check co-integration among exogenous and endogenous variables, we will apply OLS methodology. This will give us the nature and significance of the relationship that exists between Independent and Dependent Variable. The multiple structural breaks which were detected using SIS technique will also be included in the model to check the impact on Consumption of Coal.

Table 3. 21 Long run Estimated Coal model

Dependent Variable = lnC_{COALt}

	Coefficient	Std. Error	t-value	t-prob
Constant	*-5.79329*	*0.3957*	*-14.6*	*0.0000*
R_{COALt}	*0.000531*	*7.584e-005*	*7.00*	*0.0000*
Pr_{COALt}	*0.462520*	*0.1406*	*3.29*	*0.0023*
I_{COALt}	*0.232083*	*0.06457*	*3.59*	*0.0010*
Pe_{COALt}	*-0.00038*	*8.647e-005*	*-4.50*	*0.0001*

sigma	=	0.64653	RSS	=	14.6300334
R^2	=	0.879976	F(4,35)	=	64.15 [0.000]**
Adj.R^2	=	0.866259	log-likelihood	=	-36.6415
no. of observations	=	40	no. of parameters	=	5
mean(CCoal)	=	-2.78897	se(CCoal)	=	1.7679

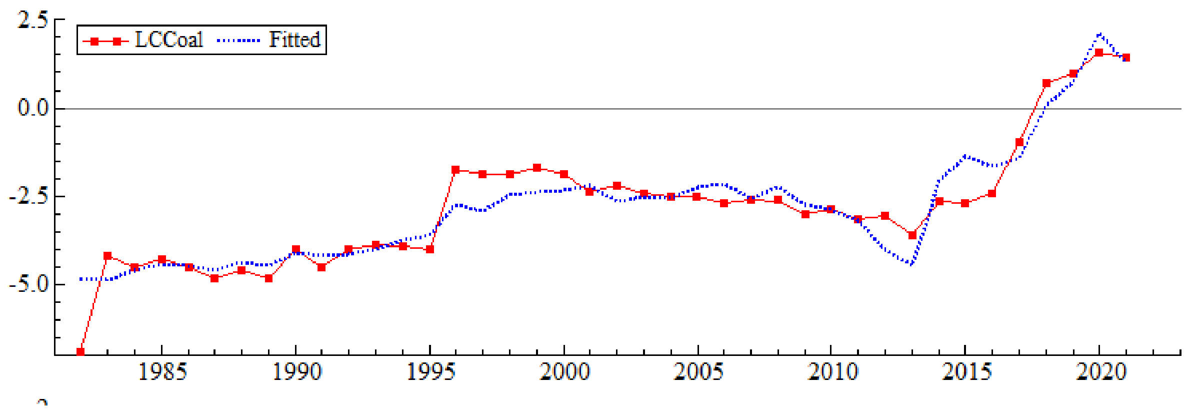


Fig. 3.18: Long Run Estimate of Coal Model

Final equation can be written as Eq 3.18

$$C_{COALt} = (-5.793) + 0.000531R_{COALt} + 0.462520Pr_{COALt} + 0.232083I_{COALt} + (-0.00038)Pe_{COALt} + \varepsilon_t \quad (3.18)$$

Test summary of the residuals can be seen in the Table 3.22

Table 3. 22 Test summary of Residuals

AR 1-2 test: F(2,33)	*1.0081 [0.3759]*
ARCH 1-1 test: F(1,38)	*2.7750 [0.1040]*
Normality test: Chi^2(2)	*8.1236 [0.0172]**
Hetero test: F(8,31)	*0.85557 [0.5629]*
Hetero-X test: F(14,25)	*0.68683 [0.7658]*
RESET23 test: F(2,33)	*0.86974 [0.4284]*

In the Table 3.22, we can see the model passes AR 1-2, ARCH 1-1, Hetero and Hetero-X and RESET test at 5% level of significance and Normality test passes at 1% level of significance which shows that residual analysis supports the model, and the results are pretty accurate.

Table 3.21. shows the OLS results of estimation. As the dependent variable is in log form, we will interpret the results by exponent ate the coefficient, subtracting one from this coefficient, and then multiplying this number by 100. The final value will show us the change in the dependent variable in percentage for one unit change in the independent variable. We have used the auto metrics function of OxMetrics, which removes the independent variables that show an insignificant relationship with the dependent variable. So, in this case, GDP per capita () shows an insignificant relationship with the consumption of coal. The possible reason could be that when GDP per capita was rising from 1981 up till 2021, Coal was not being used as a major source of producing energy in the years before 2017. Instead Oil and Gas were majorly used for fulfilling the energy demand in the country and more energy consumption in the country would lead to more economic growth in the country. Reserves of Coal () show a

significant relationship with Consumption of Coal. The coefficient is **0.000531**, which is calculated in percentage as 0.053%. This value tells us that one unit in an increase of reserves of coal will result in a 0.053% increase in the consumption of coal in the energy sector. Production of Coal also shows a significant and positive relationship with consumption of Coal in the energy sector of Pakistan. The coefficient is **0.4625**, and the calculated value in percentage is 58.8%. The results suggested that the one-unit increase in the production of coal shows a 58.8% increase in the consumption of coal in the energy sector. As Pakistan needs the cheapest sources for producing energy, and coal is currently one of them so, more production means more consumption of coal in the energy sector of Pakistan to fulfill energy demand. The Import also shows a significant and positive relationship with the consumption of coal. The coefficient is **0.2320**, and the calculated value in percentage will be 26.11%. Pakistan imports burnable coal from Afghanistan and other countries to fulfill the energy demand. Our local/Thar coal is not of very good quality, so we heavily rely on the import of Coal. The results also show that a one-unit increase in the import of coal results in a 26.11% increase in the consumption of Coal. The Price of Coal shows a negative and significant relationship with the consumption of Coal. The co-efficient is **-0.00038**, which can be calculated in percentage as -0.038%. The value shows us that a one-unit increase in the price of coal results in a 0.038% decrease in the consumption of coal in the energy sector. As world energy prices are rising and import is costing us very much, the country is trying to shift to local coal and covert the imported coal power plants to local coal plants for producing energy. This can be seen in the consumption of coal graph that after 2021, the consumption of coal decreases, showing the import issues and high rise in energy prices in the globe.

Next step is to check the presence of unit root with ADF test in the residual series obtained from co-integration analysis. After checking, it shows the value of adf-stat **-6.07**(-1.94) which neglects the null hypothesis that there is a unit root and concludes that residuals are stationary so we can now check for the presence of Error correction Mechanism in the model.

3.4.5. Parameter Stability Test

We will check the parameter stability by using Forecast Chow test to check the stability in the structure of the model and ensure that no structural break appears in the model

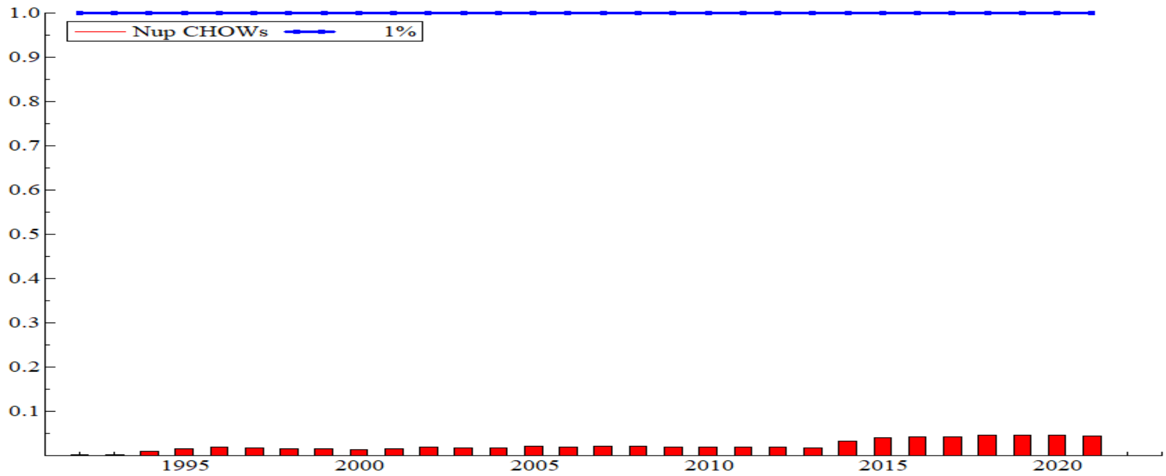


Fig.3. 19 Parameter Stability test

We can see that the bars are under 1% p-value, showing us that parameter are stable after running the regression and there is no break found in data.

3.4.7 Error Correction Model

Now to find out the presence of Error correction mechanism in the model, we will take the first difference of the significant variables and the lag of residuals obtained from long run estimation. Then we will run the OLS regression methodology. It will give us the whether the disequilibrium in the model will stabilize itself or not.

Table 3.23 Short Run analysis of Coal Model

Dependent Variable = DLC_{COALt}

	Coefficient	Std. Error	t-value	t-prob
DR_{COALt}	*0.000442*	*0.0001115*	*3.97*	*0.0003*
DI_{COALt}	*0.255598*	*0.06713*	*3.81*	*0.0005*
DPe_{COALt}	*-0.000151*	*0.0001095*	*-1.39*	*0.0493*
DPr_{COALt}	*0.266964*	*0.1226*	*2.18*	*0.0365*
ECT_1	*-0.698222*	*0.1434*	*-4.87*	*0.0000*

sigma = 0.497902d
log-likelihood = -25.4665
no. of observations = 39
mean(DLCCoal) = 0.213445

The results reveal that Error Correction Term(ECT_1) shows negative and significant value in the results. The time required in balancing the disequilibrium can be calculated as $\frac{1}{-0.69} = 1.44$ time period

3.4.8 Forecasting

After checking the co-integration, Next step is to use ARFIMA-B model to project the Consumption of Coal for the future. We have checked for stationarity in the series with Perron(1989) modified dickey fuller test with break and find stationarity in the series with Break in 2017. (The peak values at the end of the series looks like structure breaks so we will

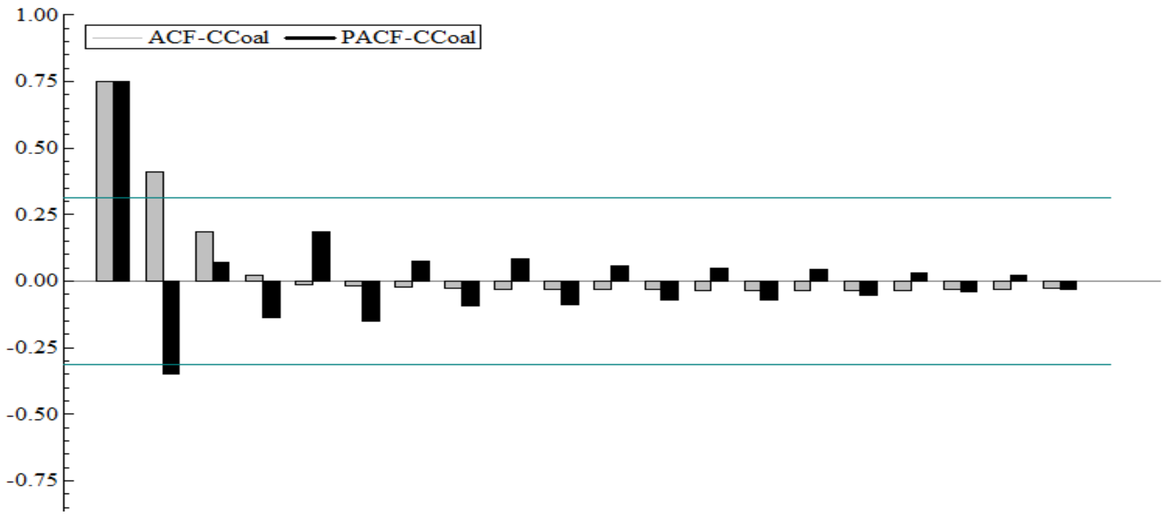


***Fig.3. 20*:** PACF and ACF plot of C_{COALt}

use IIS technique to check them). Next step is to plot the ACF PACF graph so that we could determine the different possible combinations of 'p' and 'q'. In this case we can determine that there are 2 significant lags of AR and MA in the model. The black lags are 'p' whereas 'q' have greyish lags in the plot. The fig 3.20 shows us that both AR and MA components of series present in the data

The result of ARFIMA-B projections is shown in Table 3.24 (B is used for dummy variables adjusted for structural breaks in the series)

Table 3.24 Projection results for Coal Model-ARMA-B(2,0,1)

Dependent Variable = C_{COALt}

	Coefficient	**Std. Error**	**t-value**	**t-prob**
AR-1	*1.92321*	*0.05338*	*36.0*	*0.000*
AR-2	*-0.945454*	*0.04935*	*-19.2*	*0.000*
MA-1	*0.571737*	*0.1116*	*5.12*	*0.000*
Constant	*1.94216*	*0.7525*	*2.58*	*0.014*
I:2017	*-0.351508*	*0.02206*	*-15.9*	*0.000*
I:2019	*-0.796325*	*0.03155*	*-25.2*	*0.000*
I:2021	*-2.07046*	*0.09804*	*-21.1*	*0.000*

log-likelihood	= 22.6806398		
no. of observations	= 41	no. of parameters	= 8
AIC.T	= -29.3612796	AIC	= -0.716128771
mean(CCoal)	= 0.394268	var(CCoal)	= 1.1141
sigma	= 0.0700658	sigma^2	= 0.00490921

Using Impulse Indicator Saturation Technique, we have identified significant breaks at target size of 1%. The significant breaks were in 2017, 2019 and 2021. The model came to be the most appropriate model for forecasting as it got minimum value of AIC, HQ and SC. The values came to be -0.716, -0.594 and -0.3817 respectively. We will then check the descriptive statistics of the residuals obtained from the model.

Table 3. 25 Descriptive Statistics of Residuals

Normality test: Chi^2(2)	*21.546 [0.0000]***
ARCH 1-1 test: F(1,32)	*1.7914 [0.1902]*
Portmanteau(6): Chi^2(3)	*3.6122 [0.3065]*

The p-value of ARCH 1-1 test is more than 5% level of significance; thus we can accept the null hypothesis that there is no heteroscedasticity in the model. Portmanteau p-value is also above 5% level of significance so we cannot reject null hypothesis that there is no autocorrelation in the residuals. Normality test p-value is less than 5% level of significance thus we can reject null hypothesis and accept alternative hypothesis that there is no normality in the data

Furthermore, we will diagnose the model by plot the ACF plot of Residuals. This plot is used to analyze the autocorrelation structure of residuals

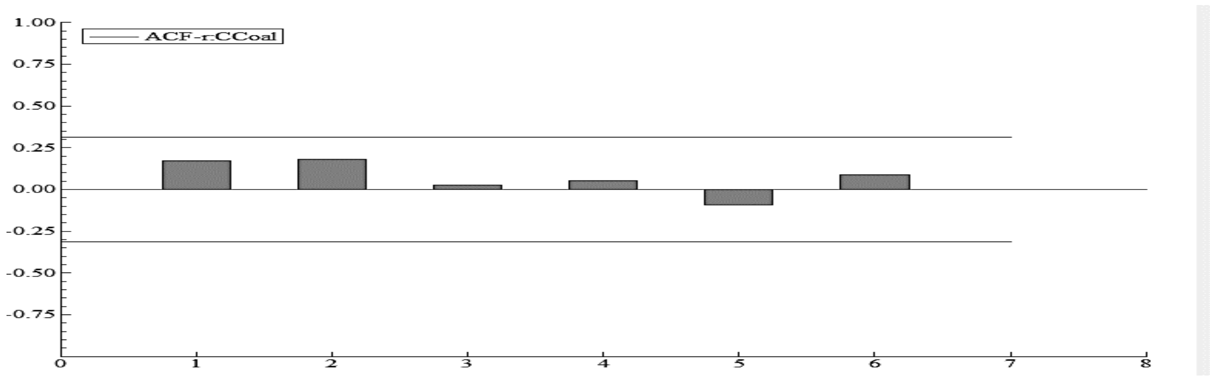


Fig.3. 21 ACF plot of Residuals

From the plot, we can see that no residual lag is crossing the significance level and we can say that the model is an appropriate model for forecasting.

Forecasting results from ARFIMA-B (2,0,1) model can be seen as Fig 3.22

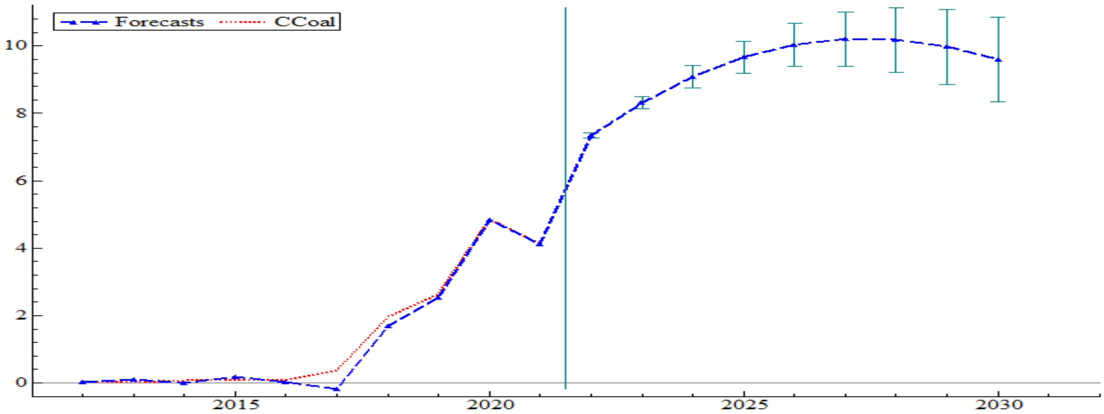


Fig. 3.22: ARFIMA-B Projections of Coal consumption

We have projected the future consumption of coal from 2022 to 2030 with ARFIMA-B (2,0,1) model. The results show us that the consumption of coal will be going upward in the coming years. The consumption will be approx. 7.31 MTOE in 2022, and it will increase up to approx. 10.20 MTOE in 2027, but afterward, it will decrease to 9.56 MTOE. As we know, coal is the cheapest source of producing Energy, and the Government has started to use coal for major production of energy from 2017 until 2020. The 2021 shows a decline because of import barriers and Expensive energy prices in the global world. Our projections tell us that Government will add more coal to the current energy mix of the country, and it will convert coal power plants that run on imported coal to local/Thar coal. One reason is that it is the country's cheapest energy source. China has already invested in coal-based power plants which will be converted into local coal-based plants in the coming years. This will ease the burden on the government, and the cost of producing energy would be less than the other two fossil fuels. Pakistan has remarkably high reserves of coal, and the Government could utilize it to produce affordable energy in the future. The decline after 2027 suggests that the Government would take steps to reduce Coal consumption in producing energy. One reason could be that international energy prices are going high and international prices of coal were going suddenly high before 2022. Another reason is the environmental hazards that are attached to the energy produced by coal. Coal is the dirtiest source of producing energy, and international laws on environmental protection are becoming stricter day by day. International Organizations are convincing countries to shift to Renewable Energy sources for producing energy, and Pakistan's latest energy policy in 2019 predicted that Renewable energy sources would have a 30% contribution to producing energy by the end of 2030. Thus, we can think that Government will try to convert coal-based power plants to Solar based plants, as one plant of coal is already in the process of converting to Solar.

CHAPTER 4

QUALITIATIVE ANALYSIS

ALTERNATIVE AND RENEWABLE ENERGY POLICY 2019

The Alternative Energy development board was first established in May 2003, by the Federal government at that time. This board was specially tasked to make sure the completion and implementation of governments policies and plans regarding energy production and energy security. Moreover, duties for the Board includes creating awareness among public regarding Renewable Energy usage, developing projects, analyzing the challenges and to promote local manufacturing sector in making Different Renewable Energy like Solar, Wind, Hydro, Nuclear etc. The published report of AEDB regarding renewable Energy gives current output of Renewable sources in producing Energy. Some of them are

1) According to 2006 data, the energy produced currently by Hydro is collectively 6,608 Mega-Watt which is less than 15% of total potential of plants in producing Energy.
2) Wind Farms are not currently functioning in the country, the potential of producing energy is good specially in south areas of Balochistan and Sindh where the speed could go to 7 to 8 meters per second
3) Solar Photovoltaic Cell has not been used significantly in industrial or household sector. No marketing has been done but the potential to produce energy from this source is quite good in southern parts of Punjab, Sindh and Balochistan specially because these areas receive at least solar radiation of over 2 Mega-Watt hour per meter square and sunshine time is 3000 hours in a single year
4) Lastly, Biomass has been used by Sugar industries to produce Electricity for their function. No other sector is currently using it, they have been allowed to give grid 700 Mega-Watt of electricity. The production of biomass is significantly high as Pakistan has much of rural livestock in the country which produce biomass in good quantity. Its

usage is mostly on household level, but it can be used as fuel to produce methane gas that could fulfil the shortage of energy in the country.

The policy further suggests the four main goals of action plan that are

1) First step is the reduction of dependency of Energy sector on Imported fuel specially Oil, Coal and Gas. A further risk is the fossil fuel transportation, supply fluctuations and price fluctuations which often caused shortage in the country in the past. So Renewable Energy would help in diversifying the overall energy mix of Pakistan.
2) The Economic benefit of Renewable sources are quite competitive as compared to traditional fossil fuel usage. The expenditure of transportation and international fluctuations in prices and imports cause millions of dollar damage to the country. Specially, renewable Energy would do well in Rural areas where Electricity is not yet reached or is quite expensive there. There would be no transportation issue or bill for RE and it would also generate employment and earning opportunities for the people of the area thus benefitting the whole economy.
3) The differences in the per unit output is quite significant between Urban and Rural Areas where modern energy supplies were not provided by the government. The burden on Rural woman to produce biomass would also decrease and the social equity could be achieved.
4) One of the big benefits is the Environmental safety that RE can assure of. As we known, the Greenhouse Gas Emissions of Fossil Fuel are remarkably high and dangerous, causing ozone depletion and diseases. The usage of RE can help significantly in environment protection by using Clean and Green Energy and it would also help in Pakistan's role in climate protection in the world. The United Nations also emphasizes it to quickly shift to Renewable Energy.

The Policy goals set by the AEDB are

1) To increase the supplies of Renewable Energy sources in the country and to achieve a higher target of 9,700 Mega-Watt in overall energy mix of the country till 2030.
2) To fill the gap of demand and supply of Energy between producer and consumers by giving its contribution.
3) Renewable Energy projects would also attract Investments from within or out of the country. It will give special incentives to investors to invest in RE, this would further help in more projects, resulting in more production and monopoly of Existing producers in Energy sector could also be finished.
4) The Projects will support the private sector for attracting investments, promoting clean energy projects and finance mobilizing across the country.
5) RE will also help in developing other social infrastructure i.e. roads, education, medical, clean water and trade etc. that will benefit the economic well-being of deprived communities.
6) RE helps in overall technical, institutional and operational capacity of energy sector.
7) Local production of RE would reduce the cost of production, supply would be quick to consumers, employment would increase and skills of labor could be improved.

The basic scope related to Renewable Energy is to create 50 Mega-watt hydro plants, increase in the usage of Solar Voltaic Cell and heat energy and third is the wind energy production.

Criticism and Suggestions

We carried out a forecasting analysis and made projections regarding the usage of Fossil Fuel in the coming 9 years in the Energy sector. The findings do not show supportive results for Renewable Energy usage in coming years and the targets of AEDB policy do not seem realistic in coming 10 years. The time span for development of Renewable Energy Plants is more than 20 years. Dams, Nuclear Plants and Wind Farms take up a lot of Country's income and the breakeven point is after 20 years on average. The second problem is their efficiency in producing energy. So, shifting in large scale from fossil fuel to Renewable Energy sources would not happen

Furnace Oil is mostly used in producing energy in Pakistan. Although we see a latest decline in 2019 in Oil consumption, our projections tell that that consumption will increase in future as Pakistan. Further Gas consumption in the sector would increase until 2030. Finally, Coal also shows an increasing trend and consumption would only decrease after 2027. These finding tells us that Consumption of Fossil fuel will remain the biggest source of producing Energy. Government is already shifting Plants to Solar power plants, but these projects take many years and political interferences also becomes an issue in Pakistan's scenario. So, we cannot really say that Pakistan would be 25 percent dependent on renewable energy sources for producing energy and 30 percent at the end of 2030.

The government could make Biomass plants on an urgent basis as these plants will take 3-4 years to develop and small households and industrial sector could be shift to the energy produced by these plants. This would also help in filling the gap of supply and demand of energy sector and environmental protection goals could also be achieved. Local demand for energy could be compensated by Solar panels which will ease the pressure on the government to produce expensive energy. This will somehow help the government in giving import bills to countries.

CHAPTER 5

CONCLUSION

After projections of these three series, i.e., Oil, Gas, and Coal for the upcoming nine years, overall results show us that consumption of Crude Oil, Natural Gas, and Coal will increase in coming years which is also supported by Rehman et al. (2017). These projections suggest that Government would give licenses to more fossil fuel power plants or attract foreign and local investments in the energy sector

1) Analyzing past trends of Oil consumption in the Energy sector, we can say after projections that it will remain a major source in producing energy, and the consumption will show a cyclic trend, but overall, it will increase little in 2030. The consumption was 2.3 MTOE in 2021; it will go up to 3.41 MTOE in 2026 and will rise again to 4.46 MTOE in 2030. The fall in 2025 suggests that Government could substitute Oil with Coal or Gas at that time, but the overall increase tells us that Oil's percentage in the overall energy mix will go higher at the end of 2030. These results are also supported by Aizel et al. (2018), who concluded that demand for Oil will go up to 29.9 MTOE in 2030. since our renewable sources are still producing only four percent of energy (NEPRA report, 2020). So the Economy will survive on Fossil fuels like Crude Oil, and consumption will increase at least till 2030. The concerning thing is Reserves and Local production of Crude Oil are showing decreasing trend from 2017 to 2020. This could result in increased Import bills as our local production is not enough to meet the current and future requirements of the country. This could also result in a Circular debt issue as we would have to pay Millions of Dollars to foreign suppliers, which would eventually result in decrement in foreign currency reserves. IPPs are already producing

very costly energy for the country, and projections tell us that the Government would be more likely to give licenses to more IPPs in the future. Increasing the usage of furnace oil in coming years is not good news at all. Likewise, Environmental sanctions and ozone layer depletion are also major concerns for the country. Producing Energy with Crude Oil will remain costly soon.

2) Consumption of Gas is showing an upward trend after 2022, at which the consumption is estimated to be 8.57 MTOE which will rise to 8.84 MTOE in 2025 and finally 9.98 MTOE in 2030. This shows that Natural Gas will be used alongside Crude Oil for production of Energy in the country. The Gas projections are supported by Aizel et al. (2018) and Rehman et al. (2017), which projected an increase in the usage of gas at the end of 2030 thermal power generation. The rate of consumption suggests that Government will use more and more Gas in the future to meet the energy requirements. There are 9 Power plants that run on Natural Gas. One Power plant was set under CPEC of 525 Mega Watt capacity. As the Renewable Energy sector is not contributing much because of underdeveloped infrastructure, Fossil fuels like Gas will be used more in the future. According to AEDB 2019 draft, the government sets the plan to convert 20% of the main source of energy to RETs (Renewable Energy Sources) by 2025 and 30 percent by 2030. Also, Fossil fuel usage causes environmental degradation of environmental, so the world is already shifting to RETs. According to our estimations, Government's plan does not seem likely to happen in the future as Energy Mix will consist of majorly Fossil Fuel for thermal power generation in the future

3) The future projections of Coal are suggesting that up till 2020, the consumption was increasing, but in 2021, the consumption of Coal will go down because of energy prices, international coal prices, and import issues as Pakistan mostly imports burnable coal

that produces energy. The projections result show that it will go up in the future till 2027, and then the consumption will go down till 2030. In 2027, the estimated consumption would be 10.20 MTOE, and at the end of 2030, the estimated consumption would decrease to 9.56 MTOE. This shows that the Government would be more likely to set up more local and imported-based coal power plants. Previously, most plants were running on Imported Coal because Local coal is not useful for combustion purposes. Many coal power plants are established under CPEC projects, majorly Thar coal power plants. 9 out of 18 power plants that were set up in Pakistan and financed by China are coal-based. 2 coal power plants are under construction, and 6 more are currently working to meet the country's energy demand. The results are supported by reports and studies such as Ministry of Planning (2021), Khalid and Jalil (2017). After 2027, consumption will go down. One reason could be that Coal is not a reliable source in the context of environmental sustainability; its price will increase in the future because energy prices have been going high in the past, and there is a deep concern in international organizations regarding the use of Coal in producing energy. The second reason is that the existing coal power plants could be converted into Renewable energy plants. Clean energy is the main goal for any country right now as this will decrease the expense of producing energy through fossil fuels.

Overall results could give valuable suggestions to the Government regarding Fossil Fuel energy consumption for the country. Our two fuels, Crude Oil and Natural Gas, show more consumption at the end of 2030, except Coal which shows more consumption in 2027. Energy shortfall is already present, so not to make matters worse, Government must act quickly and either make more power plants that could run on furnace oil and natural gas. Local coal power plant production could also result in cheap energy or establish renewable energy projects under

CPEC or any other schemes. Afterward, this plant could be converted into a Solar power plant. Failing to do so will make future energy more expensive than now.

4.1 Policy Recommendations

Oil consumption is showing upward from 2022 to 2030, giving an alarming situation that an increase in consumption will result in increased expense of government in Producing Energy. According to the latest NEPRA report, there are at least 42 IPPs (Independent Power Plants) working in Pakistan that are using Furnace oil to produce Energy, and according to them, the cost of producing energy is Rs 7-8/unit. This results in overly expensive energy, and even after IPPs, the import of Crude Oil will also increase if consumption increases. The most effective way to decrease the consumption of Oil is to quickly shift to other resources, like Coal or Gas, which are cheaper than Oil, so that the per unit cost of producing energy could be less. Hydro Power plants are also particularly good replacements as they are a source of clean energy which could fulfill the country's energy demand. If shifting is quickly not possible, the government can decrease the usage of Oil in producing energy so that environmental degradation could decrease and the per unit cost would decrease for producing energy which will, in the end, benefit every sector, including the manufacturing sector, service sector or transport sector, etc. According to a Dawn article published in December 2022, the cost of producing energy using Oil is Rs24.17 per unit. This is overly expensive, but the government has not many options in this regard. Alternative and renewable energy policy has already stated that usage of expensive fuel like furnace oil will be decreased in the future and Renewable energy sources will be majorly used to produce energy, although our projections do not support the claim.

Another fossil fuel that government can focus on is Gas. Our results predict that Natural Gas consumption will also increase in the future. Natural Gas has less Greenhouse emissions as compared to coal and Oil. Pakistan has a good amount of reserves of Gas in the country.

Multiple times bigger than its annual rate of consumption. As our renewable Energy infrastructure is not yet developed much, so relying on RETs as the main source of producing energy can prove disastrous. So Gas can replace Oil at least in producing energy which is less costly, and its share in the energy mix could be increased to fulfill the current and future energy demands of the country. Producing energy by using local gas will cost Rs7 per unit, and using imported LPG will cost Rs17 per unit. It is quite expensive but still not as much as using Furnace oil which costs us nearly Rs24 per unit. Government must shift from Oil to Gas to produce environmentally friendly energy, which will also be less costly.

Another Fossil fuel type is Coal which is used to produce Energy in Pakistan. Only one type of Coal is used in producing energy, which is Bituminous Coal. According to the HDIP report of 2020, the Production of coal decreased from 4,193 thousand tons to 3,159 tons in 2020. As compared to 2018, the shortfall is near 23.91% in 2020. Our Analysis projected that after 2021, the usage of coal will go significantly up for the energy sector. The main probable reason is that it cannot be stopped use in the energy sector, although there are issues with its import, production halts, and supply. The government is trying to convert imported-based coal power plants to local coal power plants so that the import issue can be solved, and Cheap energy can be produced. The cost is still cheap as it is estimated that in November 2022, the cost of energy production using coal is Rs12.84 per unit, which is quite affordable as compared to other fossil fuels. Our current Energy demand is still extremely high as compared to energy production in the country. Renewable Energy Technologies like Wind Farm or Dams take 20 years to complete, and this time could be increased as per government policies. Unfortunately, in Pakistan, whenever there is a regime change, the infrastructure of the Energy sector is always got affected. As still, Pakistan still has good reserves of already discovered coal, shifting from coal to Renewable is not looking possible in the coming years because of the underdeveloped infrastructure of the Renewable energy sector in Pakistan. So our projections tell us that government will possibly pick coal as a major source, and coal usage will increase in the coming years. The local coal power plants could be developed in the case that they could be converted into solar power plants. According to the latest news, the government has decided to convert three imported coal power plants to local coal power plants. Those plants are the Port Qasim Plant, Sahiwal Plant, and China Hub Plant, which totally have a capacity of producing 1.32 GW of electricity. This has been done because the import bill of coal has passed twenty billion dollars in the 2021-2022 fiscal year, and the government needs to cut the import bills.

CHAPTER 6

POLICY BRIEF

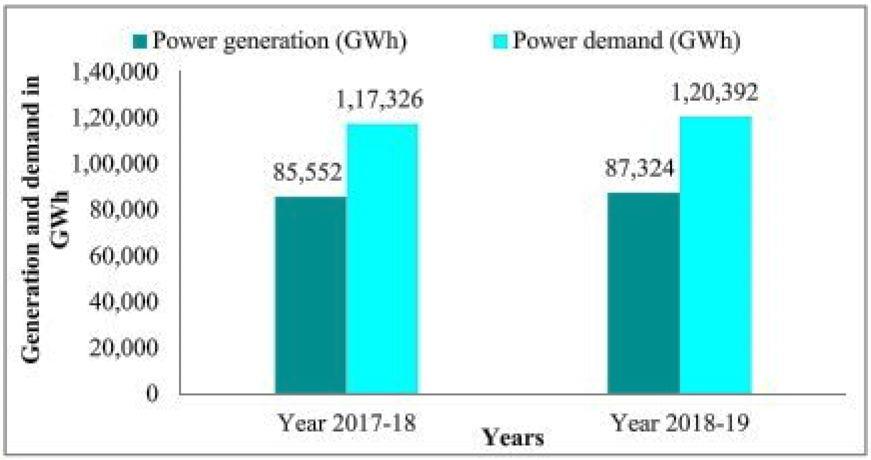
FORECASTING THE DEMAND OF CRUDE OIL, COAL AND NATURAL GAS IN ENERGY SECTOR OF PAKISTAN

5.1 Introduction

Fossil Fuel has always been a major source in producing energy for Pakistan. According to latest report of Hydrocarbon Institute of Pakistan, 73.9% of the energy produced is currently from Fossil Fuels only. This rate of consumption could be alarming as in any country; the reserves of the natural resources are limited so there exists a danger of complete depletion of resources. So to address that issue and what government of Pakistan could do to decrease the dependency on Fossil fuels, this study is being carried out to forecast the future demand of Oil, Coal and Gas in Energy Sector of Pakistan for the next 10 years. We would do analysis based on forecasting that either shifting to renewable energy is possible or not in coming years.

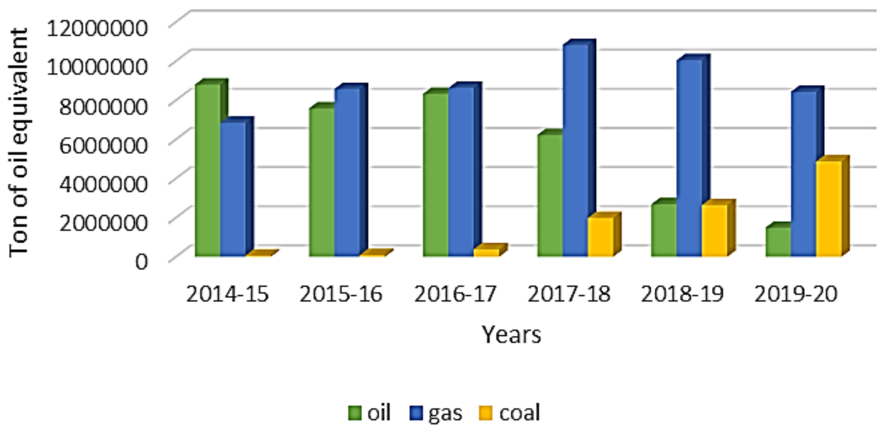
5.2 Background

The background of Energy demand is necessary to understand why Fossil fuel consumption rate remains high for last many decades. As it is evident that energy supplies were always short as compared to demand because of different issues like circular debt and inefficient energy production. From last many decades, Oil and Gas have contributed to eighty% in overall energy production. Incomplete infrastructure and low energy production played a critical role in energy shortage that country faced. The continuous increasing demand of Energy was due to average growth rate of population that was 3% per year. This increased the demand of energy in every sector, which was then accommodated by expensive energy produced from oil, gas coal and imported LPG. The failure of the Energy policy for the last few years has thrown the country into severe power crisis which then lead to weak economic growth of the country. Also the stealing, abuse and misuse of Energy in different sectors of the country resulted in overall shortage which impacted the whole economy. From Last decade, government has shown focus on Shifting to renewable energy sources to produce Energy which will be cheap and would be less burden for the country.



Fig, 5.1: Comparison of Power Generation and Power Demand

Table 1.1 shows the fossil fuel consumption in the energy sector for last 5 years. To better understand the trend, we will plot the Bar graph to check



Fig, 5.2: Fossil Fuel Consumption in Thermal Power Generation 2015-2020 (HDIP,2020)

The trend shows that Oil consumption decreases after 2017, reflecting the effects of less import, production, and decrease in reserves of Oil in the Country. After 2020, the Crude oil usage is increasing, giving us the idea that IPPs will be used again significantly for energy production in the country because of the under-developed Renewable sector

Meanwhile, Gas also showing decreasing trend after 2017, because in those years, the wells discovered were less in quantity as compared to previous years. This resulted in less availability of resources and less consumption. After 2020, consumption increases but our projections still tell us that the Gas usage will further decrease in the future pertaining to the reserves and production.

Coal shows high increase after 2017, as oil consumption decreases, the energy shortfall increases in the country. To fill the gap, Government uses the coal to fulfil that gap, although Coal has high GHG emission, but its cost is less than oil. But after 2020, the consumption falls because of the issues with import and energy prices related to coal in the global economy

Cost of producing Energy from Fossil Fuel is quite high and environmental effects are also dangerous but renewable energy projects takes decades to complete. The future projections could give us some valuable insights in how to shift quickly to RETs as they are cheaper and global economies are urging developing countries to quickly take necessary steps so that Environmental impacts could decrease.

The up and down trend became the main motivation of the study as what would be the projections in coming 9 years as the consumption behavior of these three fossil fuels is not linear. Political Regime changes, Corruption and other inefficiency factors also play role in energy sector instability.

Table 5.1: Fossil fuel consumption in thermal power generation (Ton of oil Equivalent) (HDIP,2020)

Source	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**
Oil	8,800,431	7,583,155	8,328,980	511,287	2,688,911	1,487,578
Gas	6,847,894	8,577,146	8,643,403	10,831,662	10,050,101	8,426,767
Coal	67,638	91,463	384,585	1,984,722	2,640,347	4,875,302

5.3 Objective

The following objectives were set to achieve through this analysis

1) To find out what would be the future demand of fossil fuel in energy sector for coming 9 years
2) To find out whether fossil fuel is a sustainable source to produce energy or not in the future years
3) To give the Ministry of Energy, some valuable policy points on shifting from fossil fuels to renewable energy sources.

5.4 Methodology and Findings

To project the demand of these 3 types of fossil fuel in energy sector for coming 9 years, we first check stationarity, the we use SIS technique for break detection in the series, then we applied Engle Granger co-integration to check how many independent variables and step dummies will affect the consumption of fossil fuel. Then we use IIS technique to include impulse dummies for breaks and finally ARFIMA-B modeling which will make projections about the future consumption of fossil fuel in the energy sector.

Our Findings suggest some valuable results that could provide some policy points for the government to act upon

1) After projecting the Oil demand, the results indicated that Oil would remain a major source for Energy Production. At 2026, the consumption of Oil in energy sector will be 3.39 MTOE and at 2030, the consumption value would be 4.46 MTOE and its usage will increase in the future, giving us the image that Government will use IPPs as major production industry and although the cost will be very high, but government would have no choice other than producing energy from furnace oil.
2) Gas projections tell us that after 2021, the consumption will also increase eventually in producing energy. Gas was used as a major source of producing energy in the past and to meet the future energy demand in the country, the government will either make more gas power plants or will increase supply of Gas to produce Energy. United Nations has urged the countries to shift to clean energy production and although, Gas is not a cleanest source, yet it is minimum in producing hazardous gases as compared to other two sources i.e. Coal and Oil.
3) Coal's projections show increasing trend till 2027 afterwards it decreases till 2030. The major reason is most reserves that we have in the country. Government is running import-based coal power plants but in last year, it is being announced that Imported coal power plants will be converted into Local power plants so that cheapest energy could be produced. Major imports are from Afghanistan also and import issues could also hinder the production of energy so Government major shift will possibly from Imported Coal to Local Coal or renewable energy sources such as Solar so the future energy would be cheap, and supply of sources will be fluent. Many plants have already been set up which runs on coal and being the underdeveloped country, Pakistan has no choice but to use Cheapest source for producing energy compromising its environmental impacts. The decrement in the consumption of coal after 2027 suggests

that Government could convert the existing coal power plants to solar power plants so that clean energy goals could be achieved and import bill of coal could be reduced.

Overall, the finding tells us that all three Fossil fuels consumption, such as Crude Oil, Natural Gas and Coal as sources of producing energy, will increase in the coming years except Coal which show decreasing trend after 2027. Consumption could be as high as 47 percent, and it could go high pertaining to the reason that Government is still using IPPs to produce energy and it will continue to do so in the future. In case of Gas and Coal, the supply, rising global energy prices and import issues would be the major concerns for the government so out projections confirm the government actions of converting imported based power plants to local power plants in case of Coal. These estimations can be taken as a positive as well as negative perspective. Increasing Crude Oil usage will increase Import bill which will cost the Government billions of dollars more in the future. To depend on RETs to produce major energy for the country, is looking highly less likely to happen in the future.

5.5 Future Recommendations

Our findings show valuable suggestions for the government to follow. First, the AEDB policy 2019, which says that 30% will be the target for government to shift from fossil fuel to RETs, would not be possible as the consumption rate of Oil, Natural Gas and Coal is showing upward trend in the future because of the under-developed energy sector of Pakistan. One reason is the less developed infrastructure of Renewable energy sources to produce significant amount of Energy and other reason is that projects of Renewable Energy sources take decades to complete and if political instability arises in the country, the time span could increase more. In mean time, Government has limited options like setting up fossil fuel-based power plants because energy demand will be more in the coming years based on past data.

Government could set wind, hydro, solar and nuclear power plants as many as possible, although it will not benefit in today's time, it could prove significant in producing energy in coming 20 years for Pakistan. Government has already requested Chinese financers to convert one coal-based power plant to Solar based keeping the same generation capacity. This could make cheap energy. Developing countries like Germany and other European countries are using Solar and Wind as major source of producing energy similarly in case of Pakistan, it is blessed with every type of weather. We have a major windy atmosphere in the southern part of the country and we can set wind power plants to produce energy, but it requires sincere commitment. We can start developing dams to meet the energy demand which is also very environmentally friendly.

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