Analysis of Sectoral Energy Demand in Pakistan

Raza Ali Khan[1], Mirza Faizan Ahmed[2], Jaweriya Naz Jawaid[3]
[1]Chairman, Dept. of Economics & Management Sciences
NED University of Engineering and Technology, Karachi, Pakistan, alikhan.raza@gmail.com
[2]Assistant Professor, Department of Economics and Management Sciences
NED University of Engineering and Technology Karachi, Pakistan,
mirzafaizan@cloud.neduet.edu.pk
[3]Lecturer, Department of Economics and Management Sciences
NED University of Engineering and Technology, Karachi Pakistan, jaweriyanaz@neduet.edu.pk

ARTICLE DETAILS

History
Received:
31 December 2022
Revised:
15 March 2023
Accepted:
14 March 2023
Published:
31 March 2023

Keywords
Box Jenkins
Sectoral Demand
Energy sector
Demand-Supply gap
Electricity Deficit

This is an open-access article distributed under the Creative Commons Attribution License4.0

ABSTRACT

Purpose
This research aims to estimate the energy demand for different sectors, including commercial, industrial, residential, transportation, and agriculture. For this purpose, various factors affecting the demand for energy in each sector have been analyzed.

Methodology
The adopted methodology is box Jenkins a systematic approach of identification, estimation, diagnostic checks, and forecasting of the model. This model is appropriate for time series data of medium to long-term length.

Findings
The data analysis outcomes specified that Pakistan's energy demand mainly depends on five fuel types. Within each sector, the consumption of fuel varies. Results show that 86% of energy consumption share is held by transport oil, industrial gas, industrial coal, residential gas, and residential electricity.

Conclusion
The major issue in the energy sector is the demand-supply gap primarily caused by the gas and electricity deficit. Conclusively, sectoral demand increases in each sector where commercial, residential, and industrial energy demand has higher growth. Moreover, the price effect is negative for all variables except coal, making it a Giffen good.

Corresponding author's email address: jaweriyanaz5@gmail.com

1. Introduction

Energy plays an essential role in the development of the world economy. This was stimulated by oil price shocks in late 1973 and from 1979 to 1980, with an increase in oil prices in 1999 and 2000. Due to this, attention was given to the analysis of energy demand. Demand analysis is essential for identifying the current need for energy and is dependent on the consumers' price and income. Due to various events affecting the energy market, the importance of this sector in national economies increased drastically, and significant effort was made to measure the energy demand and its factors, including income and price of energy (Aziz, Mustapha and Ismail, 2013). Energy is closely linked with economic development of a country. It is clear that higher level of GDP which is correlated with higher electricity usage, reliability and affordability (Jack, 2022).

In this regard, the demand for energy needs to be evaluated for each sector, along with the identification of factors affecting the demand for energy in Pakistan. It is important to know how much energy consumption changes due to factors influencing it, including price, income level, and productivity (Reitler, Rudolph, and Schaefer, 1987). An increase in the country's average income level leads to increased energy consumption regardless of price rise. Concerning this, a general price increase led to reduced energy demand. However, due to a rise in population and the number of connections, the demand for energy in Pakistan increased continuously (Aziz, Mustapha and Ismail, 2013). Other than this, a substitute price may also affect the energy demand. However, there is no substitute available direct to the energy while sources of energy generation may vary. People may shift to renewable energy and energy-conservative electrical appliances to minimize it consumption and overall impact generated through energy production.

However, energy is not utilized alone as it is a mix of different energy sources. These sources of energy mainly consist of five sources that create the energy mix of Pakistan. These energy sources include oil, gas, hydel, coal, and others (Wakeel, Chen and Jahangir, 2016). In relation to this, consumption of these energy sources differs in each sector, such domestic/ household consumption includes gas and electricity (Õunmaa, 2021). For commercial and industrial different sources are utilized for electricity generation, and for transportation, fuels are used (Sheikh, 2010), which is slightly shifted to electricity due to the Electrical vehicle policy in Pakistan. Currently, sector and type of fuel in each Sector in Pakistan include a higher share of transport oil 23.74%, industrial gas 18.48%, industrial coal 15.73%, residential gas 14.52%, and residential electricity 9.58%, respectively.

The availability and affordability of energy is also an important concern for developing countries, as Pakistan's energy demand is increasing rapidly. Due to this, the government is trying to meet the increasing energy demand with a stable supply of energy by adding various alternatives sources of energy, including natural resources and minerals (Malik et al., 2020). With consideration of the energy mix, Pakistan only has reserves of coal and gas, and the remaining energy sources are imported. Therefore, energy demand is affected due to international energy prices for fuel and other energy sources.

It is important to consider the price volatility in international energy markets, while modeling the energy demand. Due to increased energy prices, developing countries suffer more than developed countries because of import dependency, energy-intensive manufacturing, which takes a significant share of GDP and inefficient energy utilization (Jobling and Jamasb, 2017). Energy market volatility influences the mid- and long-term plans of the industrial sector and even the entire economy.

Energy tariffs are different for each sector due to either increased power generation costs or the government subsidizing several sectors (Trimble, Yoshida and Saqib, 2011). The energy sector is considered an important element for the progress in the current era. Therefore, demand for energy in each sector varies. This research aims to analyze the sectoral demand of energy consumers, which are divided into five sectors; household, commercial, industrial, agriculture, and government and transportation.

The remaining part of a research paper contains review of relevant research for evaluating the sectoral analysis of the energy sector in part 2, and adopted research methodology is discussed in part 3 along with a qualitative sectoral analysis energy sector in Pakistan. For measuring energy demand in each sector ARMAX model has been adopted and included in part 4, which evaluates the results from the model. The last part 5 of the paper concludes the core findings and provides policy recommendations.

1.1. Research Objectives

The Aim of this research is to estimate energy demand in different sectors including commercial, industrial, residential, transportation, and agriculture. This research aim is attained through following objectives;

1. To estimate demand of energy by major energy consuming sectors and type of fuel in Pakistan
2. To identify and analyze factors affecting the sectoral demand of energy in Pakistan

2. Literature Review

Sectoral demand analysis based on the theory of demand which defined as the way changes in the quantity of goods and services by consumers affects the price in the market. This theory states higher price of the product reduces the demand for the product inferring downward sloping of demand curve. However, demand for the product can changes even if the prices are stable. This occurs due to influence of external factors including income level, perceived quality of products, population, consumer confidence and change in taste and fashion of consumer (Mankiw, 2020). In relation to demand of energy in each sector, price, income and population are the key factors that affecting the demand for the energy in a market.

In addition to this, another theory that is relevant to this research is Box-Jenkins model which is designed for forecasting data ranges on the basis of inputs from particular time series data. This method used differences of data points in order to identify outcomes. This allows to recognize trends by using auto regression and moving averages. This research applied ARMAX model which is used for estimating demand in each sector. Basically, ARMA mode is used for forecasting which states autoregression (AR) analysis and moving average (MA) are applied in time series data by assuming that series are stationary and fluctuates uniformly around specific time period (Dougherty, 2011). This implies that factors affecting demand for energy is not limited to autoregression and moving average but there are some exogenous factors affecting demand.

Energy is considered an essential element of a country; it is contributed to socio-economic development and recognized as an important commodity (Durrani, Khan and Ahmad, 2021). However, Pakistan has been in energy crises since 2004 and the energy shortfall has reached to 5,944 megawatts. According to power division, the total power generation capacity in Pakistan has declined to 23,556 MW against its demand of 29,500MW. Due to decline in power generation, there is unannounced load-shedding period up to 10 hours of load shedding (The-Nation, 2022). Pakistan is suffering from a severe energy crisis as the supply from the distributor is limited. The underlying reason for this is continuous shortage and insufficient investment in the power sector. The shortage of electricity in different sectors increases the economy's cost. This is estimated to be around 2% of the annual GDP due to lower productivity, output, and exports (Abbasi, Abbas, and Tufail, 2021). Durrani, Khan, and Ahmad (2021) specified that the root cause of Pakistan's energy crisis is poor policy decisions with incomplete and unstable short-term planning approaches, a lack of advanced tools for accessing available resources, and a continuous increase in demand for energy.

Rauf et al. (2015) found that limited stakeholder interest, inappropriate decision-making training, and insufficient funds allocation to the energy sector make this sector vulnerable. Due to this, energy security has become a major concern for developing countries, which needs to be resolved, especially in Pakistan. Energy accessibility and appropriate tariff are essential factors behind any nation's prosperity. Therefore, long-term electricity planning in Pakistan is inclined toward a sustainable solution for electricity. This is necessary for meeting the demand-supply gap for countries suffering from severe power crises and requires long-term planning (I. E. Agency, 2018).

In relation to this, vision 2025 was developed by the Ministry of Planning, Development & Reforms of the Government of Pakistan, which will target to generate affordable and accessible energy of 42,000MW electricity by the end of 2025, which minimizes per unit average cost. This will lead to minimizing distribution losses by promoting energy-efficient appliances (Planning Commission, 2015). This vision for 2025 develops a target for Pakistan to be the largest economy globally by sustaining 7 to 8% GDP growth, which will classify Pakistan as a middle-income country. Ultimately it minimizes poverty by 50% and increases investment in the energy sector (Planning Commission, 2015).

The energy mix of Pakistan contains 61% fossil fuels, 29% hydro, 6% others, and 4% nuclear (NEPRA, 2019). However, Pakistan has a significant untapped potential for electricity generation of 150,000 MW from wind power, 100,000 MW from Thar coal, 56,000 MW from the hydro plant, and 50,000 MW from solar power (Akhtar et al., 2017). Energy demand in Pakistan mainly increases due to higher population growth of 3% per year. To meet the increasing energy demand, coal, natural gas, oil, and liquefied petroleum also increased. Pakistan's economic survey reported that energy consumption was 38.8 MTOE, which increased to 70.5mtoe in 2016 (Rehman and Deyuan, 2018). In order to meet the increasing demand for energy, it is crucial to shift to alternative energy sources instead of relying only on oil and gas. In order to sustain power generation in the long run, it is imperative to transform the energy generation mix. Historical and current consumption patterns suggest persistent growth of 8.8%, which will require 361 MTOE (Raza et al., 2022). There is a significant increase in the share of various renewable energy sources with minimal growth in nuclear power generation. The highest energy demand share is from the industrial sector, which is 35.36%, followed by the transport sector, which mainly demands fuel and oil at 32.36%, the domestic sector is around 24.50%, and the commercial sector demand is 3.97%. The overall energy consumption in different fuels across all sectors mainly shows oil and gas as the dominant fuel since 1992. However, the transport sector is the main consumer of oil. At the same time, natural gas consumption has increased in past years due to an increase in supplies of its consumption in the industrial Sector (Rehman, Cai, Fazal, Das Walasai and Mirjat, 2017).

Natural gas is the main indigenous source of energy in Pakistan. However, supply has declined over time with increasing demand on a daily basis. Gas consumption in Pakistan is higher in its energy mix compared to other Asian countries. Natural gas consumption was 28.57% in Pakistan's power sector, 23% in residential, 22.4% in industry, 14.8% in fertilizer, 7.9% in transport as CNG, and 3.2% in the commercial sector. The transportation sector has been experiencing a major shift since 1999 as government policy incentivized converting vehicles from oil to CNG. Moreover, the usage of Natural gas by industries and households for captive power has increased during the past few years due to the shortage of grid electricity (Khan, 2015). The results from Khan's (2015) study suggest that natural gas is negatively influenced by its own price and cross-price elasticity in the short and long run.

Pakistan has a higher potential for utilizing coal for energy production. It was measured that Baluchistan coal was only 1% of the total coal reserve which is sufficient to meet current and future energy demands to a great extent. The quality of Pakistan's coal lies between sub-bituminous to bituminous which contains higher Sulphur, and low ash, which is suitable for power generation. Pakistan is the world's sixth-largest country with coal reserves (Durrani, Khan, and Ahmad, 2021). Thus, the government plans to increase the share of coal in the overall energy mix. Some expert is of the opinion that coal quality is inferior with low BTU (British Thermal Unit) (Ministry of Finance, 2015); with consideration of current era modernization of technology, boilers of special quality can burn any form of coal still there is a need of true economic cost measurement.

With an increase in population, higher electricity demand cannot be deniable. The higher population growth is alarming for decision-makers to predict the future demand that may lead to worst economic instability. With consideration of this, it is important to bridge the gap and identify the demand for electricity in each sector. However, different studies have been conducted to evaluate the impact of energy shortage on economic variables, but studies related to Sector-wise analysis are limited.

Based on the research objectives following hypothesis are constructed and tested in this paper.

1. Sectoral energy demand is positively affected by income.
2. Sectoral energy demand is negatively affected by price.
3. Sectoral energy demand is positively affected by number of consumers or population.

3. Methodology

This research analyzes the current sectoral demand for energy and forecasts future demand for energy at the sectoral level. This study utilizes time series data and employs econometric models. Sources of data in this research are secondary data that have been analyzed through the quantitative model in order to make projections and estimate the impact of several factors on future energy demand and supply.

Data analysis of sectoral demand includes a transformation of data to attain the study's outcomes. Yearly data has been retrieved and analyzed from 1990 to 2019.

Data analysis initiate by checking stationary and non-stationary data. Series are stationary if the value tends to converge for the long run average and data properties change over time. Data stationery has been checked through unit root tests, including the Augmented Dickey-Fuller test and graphical presentation of data.

Sectoral demand estimation has been done through the Box Jenkins model. This model analyzed different forms of time series data for forecasting. This begins by using various data points to attain outcomes. This methodology enables the researcher to recognize trends by using autoregressive and moving averages to generate data forecasts (Wooldridge, 2012). Different diagnostic checks have been implemented to ensure no autocorrelation and heteroscedasticity issues in the data. Sectoral energy demand has been estimated by using the ARMAX model. The reason for using the ARMAX model is that series patterns depend not only on the historical trend of the series' but also on the impact of some exogenous variables.

The model used for estimation is the ARMAX (Autoregressive Moving Average with Exogeneous variables). This model includes the lags of dependent variables, previous shocks, and relevant exogenous variables as the independent variables. The general form of the model is as follows.

$$y_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, y_{t-i} + \sum_{j=1}^{q} \alpha_j \, \epsilon_{t-j} + \sum_{k=1}^{r} \gamma_k \, x_{kt} + \epsilon_t \quad \text{-------------------------(1)}$$

Where α, β, and γ are the estimated parameters. y_{t-i} is the ith lag of the dependent variable, ϵ_{t-j} is the jth lag of error or shock, x_{kt} is the kth exogenous variables. This general model uses p lags of dependent variables, q lags of shock, and r numbers of exogenous variables.

One of the major limitations of the data is its annual frequency and available length of thirty years. It does not include seasonal variations. For these fuel types of energy, including oil, coal, and LPG, consumption is considered equal to its demand. The underlying reason is that these fuels are imported, so there is no shortage. Contrarily, gas and electricity were the shortage considered while calculating the demand. Estimated sectoral energy demand and total final demand are based on the ARMAX model and CAGR for smaller proportions. Transport sector oil, industrial sector gas, coal, and electricity, and residential gas and electricity demands almost 86% of the total final energy demand.

4. Results and Discussions

4.1. Stationarity

The reason for considering the stationarity of the series is to provide a valid basis for estimating, which is said to be a stochastic process if it satisfies these conditions;

$$E(x_t) = \mu; E[(x_t - \mu)^2] = \sigma_x^2; Cov(x_t, x_{t+k}) = \gamma(k) \text{---------------------------------(2)}$$

Results from the augmented Dickey fuller test show all series are stationary except for FDIG. Along with this, the Phillips-Perron test is used, which corrects autocorrelation and heteroscedasticity in error in which all series are stationary. The summary of unit root test results is presented in table 1;

Table.1.Unit Root Test

Variables	ADF		DF-GLS		Phillips-Perron test statistic		Integrated Order
	t-Statistic	P-Value	t-statistics	P-Value	Adj. t-Stat	P-Value	
FCTO	-4.34029	0.0020	-4.31632	0.0002	-4.34029	0.0020	I(0)
FDIG	-2.44302	0.1405	-2.50041	0.02	-4.14148	0.0033	I(0)
FCIC	-4.31549	0.0022	-4.28953	0.0002	-4.40392	0.0017	I(0)
FDDG	-5.82948	0.0000	-2.67687	0.0129	-5.79544	0.0000	I(0)
FDDE	-4.04461	0.0042	-3.79365	0.0008	-4.00349	0.0047	I(0)
FCIE	-4.06144	0.0041	-3.78491	0.0008	-4.00038	0.0047	I(0)

Source: Author's own elaboration

Table.2.List of Dependent Variables

Abbreviation	Meaning
FCTO	growth in final consumption of transport oil
FDIG	growth in the final demand of industrial gas
FCIC	growth in the final consumption of industrial coal
FDDG	growth in the final demand of residential gas
FDDE	growth in the final demand of residential electricity
FCIE	growth in the final consumption of industrial electricity

Source: Author's own elaboration

4.2. Specification

This step finds the relevant value of p, d, and q. AR and MA process of the model is selected through automatic lag selection criteria. Variables of the model are stationary at level. Therefore, there is no need to define (d) in the model.

4.3. Estimation

Parameters of autoregressive and moving average terms included in the model are defined and estimated in this step. Based on this, the following model has been developed;

Table.3.Estimated Models

Model	Equations
Model 1	$\text{FCTO}_t = \alpha_0 + \alpha_1 GNPP_t + \alpha_2 \text{TTHP}_t + \alpha_3 \text{EPC}_t + \gamma_1 a_{t-1} + \gamma_2 a_{t-2} + \gamma_3 a_{t-3} + \epsilon_t$
Model 2	$\text{FDIG}_t = \alpha_0 + \alpha_1 GRSE_t + \alpha_2 \text{TGIP}_t + \alpha_3 \text{INF}_t + \gamma_1 a_{t-1} + \gamma_2 a_{t-2} + \epsilon_t$
Model 3	$\text{FCIC}_t = \alpha_0 + \alpha_1 GRIN_t + \alpha_2 \text{TCOS}_t + \alpha_3 \text{DFCIC}_t + \gamma_1 a_{t-1} + \gamma_2 a_{t-2} + \epsilon_t$
Model 4	$\text{FDDG}_t = \alpha_0 + \alpha_1 \text{GNPP}_t + \alpha_2 \text{TGRP}_t + \alpha_3 \text{GC}_t + \alpha_4 DFDDG_t + \gamma_1 a_{t-1} + \gamma_2 a_{t-2} + \gamma_3 a_{t-3} + \gamma_4 a_{t-4} + \epsilon_t$
Model 5	$\text{FDDE}_t = \alpha_0 + \alpha_1 \text{ATEP}_t + \alpha_2 \text{GRPP}_t + \alpha_3 (\text{DTCP}_t * PN_t) + \gamma_1 a_{t-1} + \gamma_2 a_{t-2} + \gamma_3 a_{t-3} + \gamma_4 a_{t-4} + \epsilon_t$
Model 6	$FCIE = \alpha_0 + \alpha_1 \text{GRSE}_t + \alpha_2 TEIP_t + \gamma_1 a_{t-1} + \gamma_2 a_{t-2} + \gamma_3 a_{t-3} + \gamma_4 a_{t-4} + \epsilon_t$

Source: Author's own elaboration

Table.4.List of Independent Variables

Abbreviation	Meaning
ATEP	growth in number of electricity connections
DFCICI	Dummy variable used for extreme values in the growth rates of industrial consumption of coal '1' for the extreme values and '0' for others
DFDDG	Dummy variables used for extreme values in the growth rate of industrial demand of Gas '1' for the extreme values and '0' for others
DTCP1	Time dummy variable, 1' for the years after 2004 and '0' for the years before 2004
EPC	Growth in CNG prices as per TOE
GC	growth in number of gas connections
GNPP	growth in per capita nominal GDP
GRIN	growth in real industrial GDP
GRPP	growth in per capita real GDP
GRPX	growth in real GDP
GRSE	Growth in real services GDP
INF	Inflation rate
PN	Growth in population of Pakistan
TCOA	growth in the international prices of Australian coal
TCOS	growth in the international prices of Australian coal
TIP	growth in the electricity tariff for industrial sector
TGIP	growth in the gas tariff for industrial sector
TGRP	growth in the gas tariff for residential sector

Source: Author's own elaboration

Table.5.Estimation Results

Dependent Variable	Independent Variables								
FCTO1	**Intercept**	**GNPP**	**TTHP**	**EPC**	**MA(1)**	**MA(2)**	**MA(3)**		
Coefficient	0.0628	0.2293	-0.4974	0.1862	-1.4391	-0.0702	0.5406		
P-Value	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
R-squared	83.7%	**Adjusted R-squared**			78.3%				
FDIG1	**Intercept**	**GRSE**	**TGIP**	**INF**	**MA(1)**	**MA(2)**			
Coefficient	-0.0561	1.4062	-0.1877	0.7188	0.2405	1.0000			
P-Value	2.1%	0.0%	0.0%	0.1%	6.0%	0.0%			
R-squared	62.8%	**Adjusted R-squared**			52.7%				
FCIC1	**Intercept**	**GRIN**	**TCOS**	**DFCIC**	**MA(1)**	**MA(2)**	**MA(3)**		
Coefficient	0.0097	1.4477	0.1643	0.0783	-0.0883	0.4882	0.6726		
P-Value	79.2%	0.2%	2.2%	1.5%	0.0%	0.0%	0.0%		
R-squared	74.0%	**Adjusted R-squared**			65.3%				
FDDG1	**Intercept**	**GNPP**	**TGRP**	**GC**	**DFDDG**	**MA(1)**	**MA(2)**	**MA(3)**	**MA(4)**
Coefficient	-0.0051	0.3580	-0.0800	0.5483	0.0358	-1.2234	0.4467	-1.2233	0.999955
P-Value	46.4%	0.0%	0.1%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
R-squared	78.8%	**Adjusted R-squared**			68.8%				
FDDE1	**Intercept**	**ATEP**	**GRPP**	**DTCP*PN**	**MA(1)**	**MA(2)**	**MA(3)**	**MA(4)**	
Coefficient	-0.0063	1.3348	0.4989	0.8698	-0.2907	0.2354	0.3476	0.5012	
P-Value	57.3%	0.0%	1.6%	4.7%	0.0%	0.0%	0.0%	0.0%	
R-squared	60.0%	**Adjusted R-squared**			44.0%				
FCIE1	**Intercept**	**GRSE**	**TEIP**	**MA(1)**	**MA(2)**	**MA(3)**	**MA(4)**		
Coefficient	-0.0039	0.9965	-0.0632	-0.0210	-0.4019	-0.9016	0.3244		
P-Value	81.7%	0.6%	1.6%	0.0%	0.0%	0.0%	0.0%		
R-squared	60.4%	**Adjusted R-squared**			47.3%				

Source: Author's own elaboration

Model 1 includes FCTO as the dependent variable, and the independent variable is growth in per capita nominal GDP, Growth in the price of high-speed diesel, and growth in CNG prices as per TOE. This model is best fitted as 83.7% is explained through this model with the pf3rd order moving average process.

Model 2 takes dependent variable growth in total final demand of industry and independent variable including growth in real service of GDP, Growth in tariff for the industrial sector, and inflation with second order moving average process. Results show that tariffs are negatively correlated with demand, while growth in real sector GDP and inflation are positively related. Due to an increase in inflation, industrial productivity increases, resulting in an increase in the consumption of gas in the industrial sector.

Model 3 consists of FCIC as a dependent variable and growth in real industrial GDP, Growth in international prices of South African coal, a dummy variable for industrial coal consumption, and third order moving average. Dependent variables are positively correlated with independent. Industrial coal shows similar results to final coal consumption with tariff, which made coal Giffen good. The model is fitted with an R-squared value of 74.0%.

Model 4 is a best-fitted model with an R-squared value of 78.8%, including FDDG, growth in per capita nominal GDP, Growth in the number of gas connections, and a dummy variable for industrial demand of gas with 4th order moving average process. Tariff is negatively related to the demand for gas in the residential sector. Nominal GDP, Growth in the number of gas connections, and dummy variables are positively correlated with the final demand for gas in the residential sector.

Model 5 includes the FDDE, growth in the number of electricity connections, growth in per capita real GDP, and time dummy variable multiplied with population growth with 4th order moving average process. The reason for taking the time dummy variable was the expansion in electricity power generation in 2004. The final electricity demand of the residential sector is positively correlated with growth in the number of electricity connections, per capita GDP, and growth in population with respect to time dummy variable.

Model 6 has an R-squared of 60.4%, which took growth in the FCIE as a dependent variable and growth in real services of GDP, and Growth in electricity tariff for the industrial sector with 4th-order moving averages. Tariff is negatively correlated which shows industrial electricity as a normal good. Real services GDP are positively correlated.

4.4. Diagnostic Check

After the model's specification, a diagnostic check ensures that model is fit to the data by applying different diagnostic tests to validate models and select the best of them. Diagnostic checking has been carried out by analyzing the autocorrelation of the series. There is no autocorrelation found in most of the models except for the one where weak autocorrelation is found which is considered adequate and forecasts are generated.

A diagnostic check applied to data is to check whether there is heteroscedasticity in data. Heteroscedasticity occurs when the standard deviation of the predicted variable is related to the previous time period and is not constant (Wooldridge, 2015). The null hypothesis is that the homoscedasticity of residuals is rejected if the p-values of the mode are correlated with F, and $\chi 2$ stats are the significance level. The results shown in table 2 are low, and the respective probabilities are higher than the significance level of 5%. Therefore, the null hypothesis is accepted, and residuals are homoscedastic.

Table.6.Heteroskedasticity Test: ARCH

Model	Heteroskedasticity Test: ARCH Results			
Model 1	F-statistic	0.014324	Prob. F(1,26)	0.9057
	Obs*R-squared	0.015417	Prob. Chi-Square(1)	0.9012
Model 2	F-statistic	0.005083	Prob. F(1,26)	0.9437
	Obs*R-squared	0.005473	Prob. Chi-Square(1)	0.9410
Model 3	F-statistic	0.009862	Prob. F(1,26)	0.9217
	Obs*R-squared	0.010616	Prob. Chi-Square(1)	0.9179
Model 4	F-statistic	1.630405	Prob. F(1,26)	0.2129
	Obs*R-squared	1.652214	Prob. Chi-Square(1)	0.1987
Model 5	F-statistic	0.212485	Prob. F(1,26)	0.6487
	Obs*R-squared	0.226975	Prob. Chi-Square(1)	0.6338
Model 6	F-statistic	0.054100	Prob. F(1,26)	0.8179
	Obs*R-squared	0.058141	Prob. Chi-Square(1)	0.8095

Source: Author's own elaboration

4.5. Sectoral Final Energy Demand

Pakistan's energy sector mainly depends on non-renewable sources, in which fossil fuels have a higher portion of energy generation, which is 62% of overall production. In comparison, natural gas and furnace oil provide 31.5% and 30.5%, respectively (PEO, 2019). Fossil fuels consist of 33.5% of hydropower of overall generation. Energy consumers are mainly divided into domestic, agriculture, industry, commercial, and transportation. Domestic and Industrial sectors are the main consumers of energy which make the energy sector complex and difficult to manage load during peak hours. On average, the growth of domestic and industrial consumers was 4.7% and 5.75%, respectively.

4.6. Final Energy Demand by Fuel type and sector

Figure 1 reflects the final energy demand in 2019 for each type of fuel in each sector. This shows that each category of fuel is consumed in the industrial sector. However, the residential sector also utilized all fuels except coal. The major fuel consumption in the industrial and residential sectors' is gas is used for electricity generation in the industrial sector and cooking purposes in the residential sector. Energy consumption in the transportation sector includes two fuels: oil and gas. The agriculture and commercial sectors have minimum energy use compared to other sectors. Currently, the industrial sector had the higher energy demand, around 26.6 mmtoe in 2019.

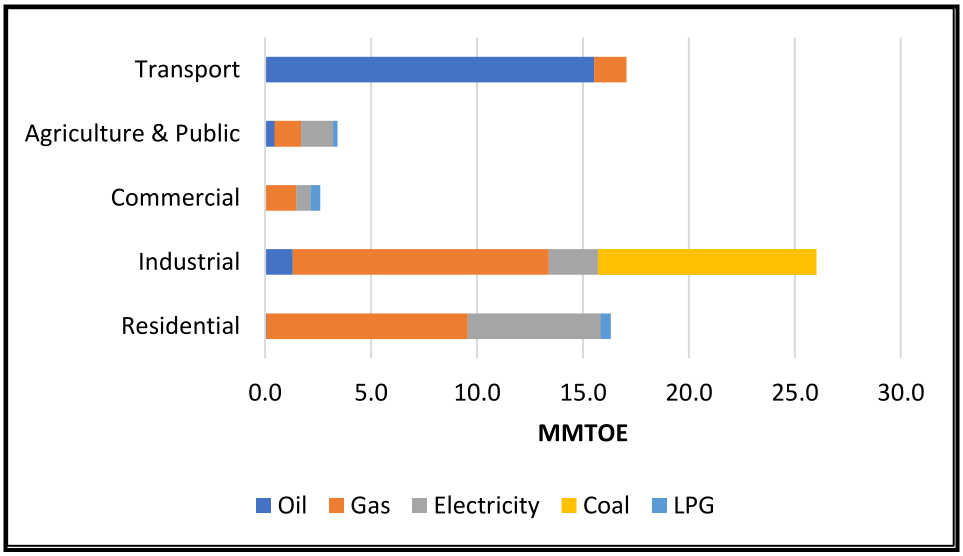

Figure.1. Final Energy Demand by Type and Sector (2019)
Source: Author's own elaboration

Contrarily, Figure 1 depicts the estimated final energy demand for each type of fuel in each sector. This indicates that overall energy demand in each sector will increase significantly; however, the proportion of each fuel is estimated to remain the same. The overall energy demand in the industrial sector is expected to be increased by 23.6%. Demand in each sector increases, in which industrial and residential sectors remain dominant, among others.

4.7. Sectoral Demand Share

Demand for different fuels varies in each sector due to their consumption requirements, as shown in Table 5. The current demand for transportation mainly relies on oil and gas, which is 26.06% of total energy. Industrial energy demand depends on all fuel types except LPG, which accounted for 39.79% of total energy, with major oil gas and coal consumption. Similarly, residential demand for energy includes all fuel except coal, with significant reliance on gas and electricity, with 24.94% of total energy demand. Conversely, demand for energy in Agriculture & Public, and commercial sectors has a minor share in the total energy mix of 5.22% and 3.98%, respectively. Commercial Oil, Transport Electricity, Residential Coal, Commercial Coal, Agriculture & Public Coal, Transport Coal, Industrial LPG, and Transport LPG have zero consumption.

Table.7.Shares of Sectoral Demand for Final Energy by Type of Fuel (2019)

Sector & Type of Fuel	Share
Transport Oil	23.74%
Industrial Gas	18.48%
Industrial Coal	15.73%
Residential Gas	14.52%
Residential Electricity	9.58%
Industrial Electricity	3.58%
Transport Gas	2.32%
Agriculture & Public Electricity	2.30%
Commercial Gas	2.24%
Industrial Oil	2.00%
Agriculture & Public Gas	1.90%
Commercial Electricity	1.05%
Residential LPG	0.74%
Agriculture & Public Oil	0.69%
Commercial LPG	0.69%
Agriculture & Public LPG	0.33%
Residential Oil	0.10%
Total	100.00%

Source: Author's own elaboration

Table.8.Shares of Sectoral Demand for Final Energy (2019)

Sectors	Share
Industrial	39.79%
Transport	26.06%
Residential	24.94%
Agriculture & Public	5.23%
Commercial	3.98%

Source: Author's own elaboration

4.8. Discussion

The results from the estimations show that there is higher energy consumption in industrial sectors, which utilize each fuel except LPG for different purposes. Therefore, the demand for energy remains higher in this sector. Similarly, the study of Durrani, Khan, and Ahmad (2021) specified that energy is an important element for economic growth as part of the productive process. Moreover, energy is inseparable from the production process of industries. In relation to this, Khan (2015) indicates that industrial development heavily depends on the supply of natural gas as it is considered a cleaner and cheaper fossil fuel than other energy sources, which leads to increased demand for gas. On the other hand, industrial consumption shows a shift from electricity to gas usage due to the interrupted supply of electricity. Natural gas usage by industries is for captive power generation due to the low availability of grid electricity. Likewise, Rehman, Cai, Fazal, Das Walasai, and

Mirjat, (2017) found that most of the natural gas consumed in the industrial sector is used to produce electricity.

The results also suggest that there is a significant portion of energy consumption from the residential sector due to the increase in population, income level and number of connections. Likewise, Khan, (2015) fund that from 1981 to 2013 natural gas consumption increases with an annual growth of 5.5% due to an increase in the usage of gas-based appliances in various sectors.

Results from this study show consumption of transport sector oil are 23.74% of total energy, which is also indicated by Durrani, Khan, and Ahmad, (2021) that primary consumers of gas include industrial, residential and transportation. Moreover, to minimize the import bill, there was a shift in the transportation sector on gas, CNG and LNG to minimize carbon emissions and decrease dependence on imported oil. In 1999, government policy was providing incentives for vehicle conversion from oil to CNG. Regardless of this, results from the study show that the share of transport gas is only 2.32%, as Waheed Bhutto et al. (2017) indicated that current consumption trend of gasoline depends on its past trends.

Estimation for coal consumption shows coal as a Giffen good in which an increase in price leads to increased demand for the product. Relatively coal price is low compared to other energy sources; therefore, if the price for coal increases, there will be no change in demand for the product. The underlying reason for this, other sources are comparatively more expensive than coal. In relation to this, Durrani, Khan and Ahmad, (2021) specified that there is a significant increase in the share of local coal projects. Whereas its share is small, it is expected to increase by 25% by 2040 in Pakistan.

Demand estimation in this study has been done by considering factors affecting energy demand. This includes price, income, price of the substitute, population growth and a number of connections. Similarly, Khan (2015) stated that medium to long-term gas demand in Pakistan depends on a single equation demand model where per-capital demand has a direct relation with real income, real prices, and real prices of a substitute. Correspondingly, Durrani, Khan, and Ahmad (2021) found that a high population growth rate, industrialization, rural gasification, and urbanization increase the demand for energy.

5. Conclusion

In this research, the box Jenkins method has been applied which used ARMAX model for the estimation of sector energy demand. It has been found that demand for energy in different sectors depends on the price, income, productivity, and inflation. Industrial sector has higher energy demand which utilized every fuel except for the LPG. Industrial coal demand is directly related with price, GDP and coal consumption. This made coal as Giffen good which remain inexpensive than other fuels even if international coal prices rise. The main industrial share is electricity that is price dependent as directly related with growth real services of GDP. Similarly, residential sector demand for mainly gas and electricity while transportation sector demand for fuel and gas. Other than these sectors, commercial and agriculture sector has small portion in energy mix. The main issue identified is the demand supply gap which is due to the electricity and gas deficit. This deficit is expected to decline if government's energy supply plan is implemented successfully, which will lead to zero difference in the coming seven years. It has been found that the primary energy supply is more inclined towards fossil fuels and more than 85% of energy consumption is from oil, gas, and coal. It is conclusive that there is higher consumption in the residential and industrial sectors. The underlying reason for this is lower access by the residential sector and inefficient consumption. In this regard, with population growth, energy demand and supply will increase in the future, but it will remain comparatively lower than the global trend.

5.1. Policy Recommendations

From the above analysis and conclusion lead to recommend that the data provided by the concerned authorities related to the energy is limited and printed with significant delay. Generally, the data of a period is printed after one year or more. The frequency of the data is yearly, which makes the analysis very limited and eliminates the possibility of incorporating seasonal variations. There is a lack of cost and efficiency measures for wells and plants. Hence, it requires developing a comprehensive and highly updated database of Pakistan's energy sector. Without the required information, no planning can be undertaken.

Author Contributions:

Dr. Raza Ali Khan: Conceptualization, reviewing. Dr. Mirza Faizan Ahmed: Methodology, formal analysis, results estimation. Jaweriya Naz Jawaid: Writing original draft, tabulation of data, formal analysis, reviewing and editing. response to reviewers' comments

Funding: This research is extracted from Pakistan Energy Outlook 2020 which was funded by PIP.

Conflicts of Interest: The authors declare no conflicts of interest.

References

Abbasi, K. R., Abbas, J., and Tufail, M. 2021. "Revisiting electricity consumption, price, and real GDP: A modified sectoral level analysis from Pakistan. Energy Policy", 149, 112087.

Akhtar, J., Yaqub, M.I., Iqbal, J. and Sheikh, N. 2017. "Way forward in meeting energy challenges in Pakistan Way forward in meeting energy challenges in Pakistan." *Int. J. Ambient Energy*, 39, 904–908. doi: 10.1080/01430750.2017.1341430

Jack, K. 2022. "How much do we know about the development impacts of energy infrastructure?" Https://blogs.worldbank.org/energy/how-much-do-we-know-about-development-impacts-energy-infrastructure#:~:text=Energy%20infrastructure%20may%20contribute%20to,may%20constrain%20output%20when%20unavailable.

Õunmaa, L. 2021. "What are the socio-economic impacts of an energy transition? | United Nations Development Programme." Https://www.undp.org/eurasia/blog/what-are-socio-economic-impacts-energy-transition.

Alternative Energy Development Board, 2013. "Data Collection Survey on Renewable Energy Development in Pakistan." Https://openjicareport.jica.go.jp/pdf/12086740_01.pdf

Aziz, A. A., Mustapha, N. H. N., and Ismail, R. 2013. "Factors affecting energy demand in developing countries: A dynamic panel analysis." *International Journal of Energy Economics and Policy*, 3(4), 1-6.

Dougherty, C. 2011. "Introduction to econometrics." *Oxford university press*.

Durrani, A. A., Khan, I. A., and Ahmad, M. I. 2021. "Analysis of Electric Power Generation Growth in Pakistan: Falling into the Vicious Cycle of Coal." Eng, 2(3), 296-311. doi: https://doi.org/10.3390/eng2030019

I. E. Agency 2017. "Digitalization and Energy; IEA: Paris, France, 2017."

I. E. Agency 2018. "Global EV Outlook 2018; IEA: Paris, France, 2018."

Jobling, A. and Jamasb, T. 2017. "Price volatility and demand for oil: A comparative analysis of developed and developing countries." *Economic Analysis and Policy*, 53, 96-113. doi: https://doi.org/10.1016/j.eap.2017.01.001

Jones, G.A. 2016. "The 21st century population-energy-climate nexus." *Energy Policy 2016*, 93, 206–212. doi: https://doi.org/10.1016/j.enpol.2016.02.044.

Malik, S., Qasim, M., Saeed, H., Chang, Y. and Taghizadeh-Hesary, F. 2020. "Energy security in Pakistan: Perspectives and policy implications from a quantitative analysis." *Energy Policy*, 144, 111552. doi: https://doi.org/10.1016/j.enpol.2020.111552.

Mankiw, N. G. 2020. "Principles of economics." Cengage Learning.

Ministry of Finance, 2019. "Chapter 14 Energy." Https://www.finance.gov.pk/survey/chapter_20/14_Energy.pdf

Ministry of Planning Development & Special Initiatives, 2018. "11th five-year plan (2018 to 2023)" *Chapter: 19-Energy*. Https://www.pc.gov.pk/uploads/plans/Ch19-Energy1.pdf.

Nadimi, R. 2018. "Energy use analysis in the presence of quality of life, poverty, health, and carbon dioxide emissions." *Energy 2018*, 96, 671–684. https://doi.org/10.1016/j.energy.2018.03.150.

NEPRA, 2019. "Power Systems Planning. Indicative Generation Capacity Expansion Plan (2018-40). 2019." Https://nepra.org. pk/Admission%20Notices/2019/09-September/IGCEP%20Plan%20(2018-40).pdf.

Perwez, U., Sohail, A., Hassan, S.F., and Zia, U. 2015. "The Long-Term Forecast of Pakistan's Electricity Supply and 30 Demand: An Application of Long-Range Energy Alternatives Planning." *Energy 2015,* 93, 2423–2435. doi: 10.1016/j.energy.2015.10.103.

Planning Commission. 2015. "Pakistan Vision 2025 (One Nation-One Vision). 2015." Https://www.pc.gov.pk/uploads/ vision2025/Pakistan-Vision-2025.pdf.

Rauf, O.,Wang, S., Yuan, P. and Tan, J. 2015. "An overview of energy status and development in Pakistan. Renew." *Renewable and Sustainable Energy Reviews*. 2015, 48, 892–931. doi: https://doi.org/10.1016/j.rser.2015.04.012.

Reitler, W., Rudolph, M., and Schaefer, H. 1987. "Analysis of the factors influencing energy consumption in industry: a revised method." *Energy Economics*, 9(3), 145-148. doi: https://doi.org/10.1016/0140-9883(87)90019-3

Sheikh, M. A. 2010. "Energy and renewable energy scenario of Pakistan." *Renewable and Sustainable Energy Reviews*, 14(1), 354-363. doi: https://doi.org/10.1016/j.rser.2009.07.037.

The-Nation, 2022. "The Pakistan's electricity shortfall reaches 5,944 MW (2022)." https://www.nation.com.pk/10-Aug-2022/pakistan-s-electricity-shortfall-reaches-5-944-mw#:~:text=The%20electricity%20shortfall%20in%20Pakistan,the%20demand%20of%2029%2C500MW.

Trimble, C., Yoshida, N. and Saqib, M. 2011. "Rethinking electricity tariffs and subsidies in Pakistan." *World Bank Report Number: 62971-PK*. Https://documents1.worldbank.org/curated/pt/870571468286264114/pdf/629710ESW0whit0020110Final00PUBLIC0.pdf

Waheed Bhutto, A., Ahmed Bazmi, A., Qureshi, K., Harijan, K., Karim, S. and Shakil Ahmad, M. (2017). "Forecasting the consumption of gasoline in the transport sector in Pakistan based on ARIMA model." *Environmental Progress & Sustainable Energy*, 36(5), 1490-1497. doi: https://doi.org/10.1002/ep.12593

Wakeel, M., Chen, B., and Jahangir, S. 2016. "Overview of energy portfolio in Pakistan." *Energy Procedia*, 88, 71-75. doi: https://doi.org/10.1016/j.egypro.2016.06.024

Winarno. T.O. 2006. "LEAP Energy Planning Guide; Center for Energy Policy Studies, Institute Teknologi Bandung: Bandung, Indonesia, 2006." *SHS Web of Conferences 49, 02007 (2018).* doi: https://doi.org/10.1051/shsconf/20184902007

Wooldridge, J. M. 2012. "Introductory econometrics: a modern approach (upper level economics titles)." Southwestern College Publishing, Nashville, T ATN, 41, 673-690.

Wooldridge, J. M. 2015. "Introductory econometrics: A modern approach. Cengage learning."