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Estimating Sectoral Energy Demand in Pakistan

Raza Ali Khan[1], Mirza Faizan Ahmed[2], Jaweriya Naz[3]

[1] Professor, Chairman, Department of Economics & Management Sciences, NED University of Engineering and Technology, Karachi, Pakistan. Email: alikhan.raza@gmail.com
[2] Assistant Professor, Department of Economics & Management Sciences, NED University of Engineering and Technology, Karachi, Pakistan. Email: mirzafaizan@cloud.neduet.edu.pk
[3] Lecturer, Department of Economics & Management Sciences, NED University of Engineering and Technology, Karachi, Pakistan. Email: jaweriyanaz5@gmail.com

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ABSTRACT

The energy sector is fuel for the development of the economy as it affects multiple sectors. Consideration of socio-economic impact, it is essential to plan for sustainable energy. For optimal energy usage, it is important to identify demand and supply in Pakistan along with existing challenges. This research aims to estimate Pakistan's energy demand for all five sectors: industrial, residential, transportation, commercial, and agriculture. Different factors have been recognized and analyzed for this research aim that influence the energy demand in each sector. This study Applied box Jenkins which followed systematic procedures including identification, estimate, analytical check, and forecasting of the model. This approach is relevant for the medium- and long-term time series data. The results indicate that the final energy demand is affected by different factors among which the main factor is the applied tariff in that sector and the real GDP of Pakistan. Consumption of each source of energy varies in each sector. From the overall analysis, it has been found that the major share of energy is from transportation oil which accounts for 27.5%, followed by a second share of 12.9% of industrial gas at 12.9%, domestic gas at 12.0%, and industrial coal at 20.4%. From the analysis of the results, the core issue in the energy sector is a gap in energy demand-supply in Pakistan due to a deficit of oil and gas and import dependency. Compared to the previous year's result it has been found that there is an increase in each sector with higher growth in industrial, residential and commercial demand. Price and real GDP were effective in determining the demand for energy sources in each sector. Based on the results, it is recommended to minimize dependency on imported energy sources and promote innovative and sustainable energy production.

Corresponding Author's Email: jaweriyanaz5@gmail.com

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1. Introduction

Energy is considered as an essential element for sustainable economic growth. The Energy sector of Pakistan is affected due to several issues. Pakistan economy covered with several

challenges that find its roots in global and local factor that has challenge of sustainable energy supply. Additionally, increase international fuel prices, unstable energy market has posed government to increase in energy prices in the country. The impact of these factors multiplies due to currency devaluation. The situation has raised issues of affordability other than sustainable energy supply. Higher energy prices lead to increase in inflation and lower economic growth which left the government with limited options for sustainable and uninterrupted supply of energy.

Primary energy here refers as total energy obtained from domestic production and import, while final energy incorporates transformation, transmission and distribution losses, auxiliary consumption and power plants in the generation process. This is the final energy consumed by different sectors of the economy and final energy always less than primary energy supply.

Mainly, users of energy, consuming five types of energy and fuel. Industrial sector is the main consumer that is followed by transport, residential, agriculture and public and commercial sector. There is main five energy sources among which largest consumption is of gas that is followed by oil, electricity, coal and LPG.

Energy plays a central role in driving global economic development. However, demand has increased due to population growth, industrial and economic development in different emerging economies. This is due to abrupt oil price shocks in the late 1970s, as well as in 1979 to 1980, and subsequent spikes in oil prices in 1999 and 2000. These events intensified the need for understanding energy demand. An in-depth comprehension of demand is vital for assessing current energy requirements, closely intertwined with consumer prices and income levels. As various events continued to exert influence on the energy sector, its importance in economies that experienced a substantial surge. Consequently, extensive efforts were dedicated to quantifying demand for energy and its determinants, encompassing several factors such as income and applied tariffs (MUSTAPHA & ISMAİL, 2013).

In this context, it becomes imperative to estimate energy demand within each sector while identifying the factors that exert an influence, particularly in the context of Pakistan. It is crucial to discern how changes in variables such as price, income levels, and productivity impact energy consumption. With growth in an average income level of country, energy demand also increases regardless of increase in price. Although, a general rise in price levels tends to reduce energy demand MUSTAPHA and ISMAİL (2013); but due to population growth and an increasing number of new connections, demand in Pakistan continues to rise. Furthermore, while substitutes may influence energy demand, direct substitutes for energy are limited. However, energy sources for generation can vary, and people may transition to alternative sources that is renewable energy and energy-efficient appliances to reduce consumption and minimize environmental impact.

The study of Wakeel, Wakeel, Chen, and Jahangir (2016) emphasized that energy isn't sourced from a single origin; it comprises a blend of five main sources in Pakistan including: oil, gas, hydropower, coal, and others. The demand for these sources of energy varies across sectors. For instance, gas and electricity are used in domestic households, while commercial and industrial sectors employ various sources for electricity generation. Transportation primarily relies on fuels, although it is expected that there will be a shift toward electric vehicles due to Electrical Vehicle policy in Pakistan (Sheikh, 2010). Presently, in Pakistan, the energy sector's composition includes a significantly higher share for transportation sector oil at 23.74%, industrial gas at 18.48%, industrial coal at 15.73%, residential gas at 14.52%, and residential electricity at 9.58%.

Pakistan's energy sector predominantly relies on conventional energy sources, with fossil fuels playing a significant role by contributing 62% of the total energy production. To break it down further, natural gas and furnace oil account for 31.5% and 30.5% of the energy mix,

respectively, as reported by the Pakistan Energy Outlook in 2020. Fossil fuels also contribute 33.5% to the overall hydropower generation.

In Pakistan, energy consumers are categorized into several sectors, including domestic, agriculture, industry, commercial, and transportation. Among these sectors, the domestic and industrial sectors stand out as the primary energy consumers. However, this poses challenges in managing energy load during peak hours specified by the suppliers. The growth rate of energy demand by residential and industrial consumers has been approximately 4.7% and 5.75%.

An important concern for the emerging economies like Pakistan related to energy is its availability and affordability as energy demand continues to surge. To meet this demand, the government is actively seeking renewable energy sources, which is generated from hydro, wind, solar and other (Malik, Qasim, Saeed, Chang, & Taghizadeh-Hesary, 2020). Notably, Pakistan possesses reserves of coal and gas, while other energy resources are imported in the country. Consequently, international energy prices for fuel exert significant influence on energy demand.

In modeling energy demand, it's vital to consider the international price fluctuation. Developing countries are particularly vulnerable to price fluctuations due to higher dependency on import, higher demand in manufacturing sectors, which account for a substantial share of GDP (Jobling & Jamasb, 2017). Additionally, Trimble, Trimble, Yoshida, and Saqib (2011) discussed that energy tariffs differ across sectors, either reflecting the cost of power generation or government subsidies). The energy sector is a key player of progress in the modern era, due to which energy demand varies across sectors. This study aims to estimate the current energy demand in Pakistan and compare the demand with the previous findings from sectoral demand analysis in (Raza, Faizan, & Naz, 2023).

The purpose of this research is to calculate Pakistan energy demand which consumers are divided into five categories including commercial, industrial, residential, transportation and agriculture. This research measure energy demand by sector and fuel type in Pakistan. Moreover, this also analyzes different factors for affecting sectoral demand of energy in Pakistan.

This research paper includes through studies of previous literature for energy demand in Pakistan under Section 2 that is followed by a discussion of the applied research methodology presented in section 3 containing information about quantitative demand analysis. Moreover, section 4 consists of application of ARMAX model applied for measuring current energy demand in Pakistan. Along with this, this part also compares the results with previous findings from the literature. Last section concludes the key findings and suggest policies to be adopted in energy sector.

2. Literature Review

Energy is a fundamental cornerstone of any nation, contributing significantly to its socio-economic development and being widely acknowledged as a vital commodity. Unfortunately, Pakistan has contended with an energy crisis since 2004, resulting in a staggering energy deficit of 5,944 megawatts. The power division reports a decline in Pakistan's total power generation capacity to 23,556 MW against a demand of 29,500 MW. It is reported that this shortfall has led to unannounced power cuts lasting up to 10 hours. Pakistan faces a severe energy crisis due to limited supply from distributors, primarily stemming from persistent shortages and inadequate investments in the power sector. Abbasi, Abbas, and Tufail (2021) emphasized on the consequences of electricity scarcity are reverberate throughout various sectors, inflicting an estimated 2% reduction in annual GDP, driven by reduced in productivity, output, and exports. The root causes of energy crisis in Pakistan's poor policy making, short-sighted planning, a lack of robust resource assessment tools, and the ever-increasing energy demand (Durrani, Khan, & Ahmad, 2021). Rauf, Wang, Yuan, and Tan (2015) further underscore the vulnerability of the

energy sector due to lack of stakeholder interest, suboptimal decision-making, and inadequate funding allocation. Consequently, ensuring security for energy is an imperative for developing countries, particularly in the context of Pakistan. Moreover, accessibility and reasonable tariffs for energy are pivotal factors for a prosperity of any nation. Thus, electricity planning for long-term in Pakistan is geared towards development of sustainable solutions to bridge the energy demand-supply gap (Agency, 2018).

With consideration of vision of Development & Reforms of the Government, Pakistan's Ministry of Planning crafted Vision 2025 (Commission, 2015). This strategic plan aims to generate 42,000 MW of affordable and accessible electricity by the end of 2025, with a focus on minimizing per-unit average costs and reducing distribution losses through the promotion of energy-efficient appliances (Commission, 2015). The plan envisions a 50% reduction in poverty rates and a surge in investment in the energy sector.

The primary driver of increased energy demand in Pakistan is its rapidly growing population by 1.98% in 2023 increased to 240,485,658. In order to fulfill this escalating demand, the usage of alternative energy sources has surged such as coal, natural gas, oil, and liquefied petroleum. Rehman and Deyuan (2018) mentioned that this shift is reflected in Pakistan's economic survey, with consumption of energy rising from 38.8 MTOE to 70.5 MTOE in 2016. For meeting the long-term growth in demand, it is essential to diversify energy mix. Raza et al. (2022) suggested stable growth of 8.8% on the basis of current and historical pattern.

Renewable energy sources share in energy mix has increase in various sector which minimizes nuclear power generation growth. The higher consumption of energy in the industrial sector with 35.36%, with second higher in transportation sector that is primarily reliant on oil, at 32.36%. Other than this, domestic demand accounts for roughly 24.50% of energy consumption and least demand is from the commercial sector around 3.97%. Rehman, Cai, Fazal, Das Walasai, and Mirjat (2017) indicates that across all sectors, oil and gas have dominated the energy consumption landscape since 1992. However, the transport sector stands out as the main consumer of oil, while natural gas consumption has steadily increased, particularly in the industrial sector.

Pakistan has substantial capacity for energy generation through coal and natural gas. Although supply of natural gas has declined overtime due to higher demand. Compared to other Asian countries, Pakistan has higher gas consumption in its energy mix. Main consumers of natural gas are domestic, industrial and transportation. There is significant increase in consumption of transportation sector in 1999 due government policy for vehicle conversion from oil to CNG (Abas, Kalair, & Khan, 2015). On the other hand, Pakistan has sixth largest reserves of coals in which mostly found in region of Baluchistan in which the quality of coal ranges from sub-bituminous to bituminous, that is found to be suitable for energy generation (Durrani et al., 2021). The use of coal for the energy production raises environmental concerns, nonetheless, modernization of technology has rendered boilers capable of efficiently burning various coal types. However, accurately measuring the true economic cost remains an essential endeavor.

With decades of suffering from electricity shortage from which each sector suffers but country finds itself with new issue of higher electricity generating capacity than its requirements. There is large-scale construction of new power plant by China that dramatically boosted energy capacity of Pakistan. Regardless of this development, there is still power outrages with transmission problem which left the major cities in dark. Development of energy capacity from fossil fuel also increase electricity cost increase concern for climate change goals. This is due to fact that coal base plants eliminated from the world energy mix in order to prevent worst climate change impact (Ebrahim, 2021). The projected increase in electricity demand will be 19% from 2025 to 2030 and generation will exceed from energy demand in coming years. In addition to this, the government made significant portion of payment for energy as the capacity charges made by central power purchasing authority. These payments backed by the electricity shortage

issues in 1994, for strengthening the power sector and attracting foreign investment, the government come up with the policy for independent power producers and capacity charges were introduced (Farooqi, Farooqi, Sajjad, Yan, & Victor, 2023). This ultimately increase government payment for these plants even if these plants are not operated at its maximum capacity.

The rapid increase in population leaves no room to deny the escalating demand for electricity. The alarming growth rate of the population poses a significant challenge for decision-makers, as it can lead to severe economic instability. To bridge this gap and accurately gauge electricity demand in each sector, it is imperative to conduct sector-wise analyses. However, while several research studies conducted which explored the impact of energy shortages on economic variables, research focusing on sector-specific analyses and comparative changes in demand remains limited.

3. Research Methodology

The purpose of this research is to estimate the current and forecast future sectoral energy demand. The study relies on historical data and use econometric models for analysis. Secondary data sources including world energy outlook, energy book, outlook (2022) , news articles, research articles, and other publications are utilized, and a quantitative model is employed to project future energy demand and evaluate the influence of various factors.

The analysis of sectoral demand involves data transformation to derive meaningful outcomes for the study. Yearly data from 1990 to 2021 is retrieved and scrutinized. The initial step in data analysis involves verifying the stationarity or non-stationarity of the data. Data series are considered stationary when values tend to converge around averages in long-run and exhibit properties that do not fluctuate significantly. Stationarity is assessed using unit root tests, including the Augmented Dickey Fuller, Dickey Fuller, and Philips perron test for stationarity.

To estimate sectoral demand, the study utilizes the Box Jenkins model, which is well-suited for analyzing time series data for future estimation. This process commences by using multiple points of data in order to extract meaningful insights. The methodology enables researchers to identify trends by employing AR and MA process to make forecasts based on the data (Wooldridge, 2012). For diagnostic checks ARCH test has been conducted to ensure that in data there are no issues related to multicollinearity and heteroscedasticity.

The applied model is used for the estimation of demand; therefore, variables of the research include factors affecting the demand of the product, this includes price, income, inflation and other factors affecting the energy demand in each sector. The estimation of sectoral energy demand is carried out using the ARMAX (Autoregressive Moving Average with Exogenous Variables) model. This choice is made because series patterns are not solely dependent on their past values but are also influenced by external variables.

In essence, the ARMAX model incorporates lagged dependent variables, past shocks, and pertinent exogenous variables as independent factors in the estimation process.

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

In this general model, the estimated parameters include α, β, and γ. The variables are defined as follows: y_(t-i) represents the ith lag of the dependent variable, ϵ_(t-j) denotes the jth lag of the error or shock, and x_kt represents the kth exogenous variable. This model incorporates p lags of dependent variables, q lags of shocks, and r exogenous variables.

Table 1
Research Variables

Variable	Description
D3	Time dummy with value 1 from 2008 onwards and 0 before 2008
D4	Time dummy with value 1 from 1994 to 2003 & from 2007 to 2021 and 0 in other periods
GATPG	Change in the access to pipeline gas connections
GCGDP	Growth in Nominal GDP
GELCR	Growth in Residential Electricity Customers
GFCIC	Growth in final coal consumption by industrial sector
GFCTO	Growth in final oil consumption by transport sector
GFD	Growth in final demand of energy
GFDDE	Growth in final electricity demand by domestic sector
GFDDG	Growth in final gas demand by domestic sector
GFDIE	Growth in final electricity demand by industrial sector
GFDIG	Growth in final gas demand by industrial sector
GGDPD	Growth in GDP deflator / Inflation
GNEPGR	Growth in nominal gas tariff for residential customers
GPES	Growth in primary energy supply
GPOP	Growth in population
GRGDP	Growth in real GDP 2015-16
GTELI	Growth in electricity tariff for industrial sector
GTELR	Growth in electricity tariff for residential sector
GTGACP	Growth in natural gas tariff for captive power
GTGAI	Growth in natural gas tariff for industrial sector
GTTRD	Growth in the domestic price of high speed diesel
GUSPK	Growth in USD/PKR exchange rate
INF	Inflation

A notable limitation of the data is its annual frequency, spanning a relatively short period of thirty-two years. It does not encompass seasonal variations. For fuel types such as oil, coal, and LPG, consumption is equated with demand, as these fuels are imported, and its shortage are not incorporated. Conversely, when calculating demand for gas and electricity, shortages are taken into account. Sectoral demand for energy is estimated through ARMAX model and Compound Annual Growth Rate (CAGR).

4. Results and Analysis

4.1. Unit Root Test

The motivation behind assessing the series' stationarity in order to establish a sound foundation for result estimation. It is a stochastic process provided to meets these specified conditions;

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

The outcomes of the augmented Dickey-Fuller test indicate that all the series are stationary. Additionally, we employ the Phillips-Perron test to address autocorrelation and heteroscedasticity in the error term, and it confirms that all the series are also stationary. Results generated from the unit root test of the series presented in the table below;

Table 2
Stationarity for unit root testing

Variables	Augmented Dickey Fuller		Dickey Fuller -GLS		Phillips-Perron		Integration order
	t-Stat	P-Value	t-stat	P-Value	Adj. t-Stat	P-Value	
GFCTO	-3.53563	0.0009	-4.73359	0.0001	-3.42502	0.0013	I (0)
GFDIG	-2.27035	0.0247	-4.89408	0.0000	-4.51726	0.0001	I (0)
GFCIC	-3.81853	0.0004	-4.57998	0.0001	-4.08069	0.0002	I (0)
GFDDG	-3.26974	0.0256	-2.04528	0.05	-3.2499	0.0267	I (0)
GFDDE	-5.6003	0.0001	-0.41329	0.6832	-5.661973	0.0001	I (0)
GFDIE	-2.30794	0.0226	-4.4794	0.0001	-2.12687	0.0342	I (0)
GFD	-2.07318	0.0385	-4.54171	0.0001	-1.8355	0.0639	I (0)

This step determines the appropriate values for p, d, and q. The AR and MA processes of the model are chosen using criteria of automatic lag selection. Since the variables are already stationary at the level. Thus, (d) should not specified in this. This step defines and estimate the parameters for the AR and MA terms incorporated into the model. On this basis, models have been developed which are presented below;

Table 3
Model Estimation

Model	Equations
Model 1	Equation 1
	$\mathrm{GFCTO}_t = \beta_0 + \beta_1 \mathrm{GFCTO}_{t-1} + \beta_2 \mathrm{GFCTO}_{t-2} + \alpha_1\epsilon_{t-1} + \alpha_2\epsilon_{t-2} + \gamma_1 GTTRD_t + \gamma_2 GCGDP_t + \gamma_3 GPOP_t + \epsilon_t$
Model 2	Equation 2
	$\mathrm{GFDIG}_t = \beta_0 + \beta_1 \mathrm{GFDIG}_{t-1} + \alpha_1\epsilon_{t-1} + \alpha_2\epsilon_{t-2} + \alpha_3\epsilon_{t-3} + \alpha_4\epsilon_{t-4} + \gamma_1 GCGDP_t + \gamma_2 \mathrm{GTGAI}_t + \gamma_3 \mathrm{GGDPD}_t + \gamma_4 \mathrm{D4}_t + \epsilon_t$
Model 3	Equation 3
	$\mathrm{GFCIC}_t = \beta_0 + \beta_1 \mathrm{GFCIC}_{t-1} + \beta_2 \mathrm{GFCIC}_{t-2} + \beta_3 \mathrm{GFCIC}_{t-3} + \beta_4 \mathrm{GFCIC}_{t-4} + \gamma_1 GGDPD_t + \gamma_2 \mathrm{GTGACP}_t + \gamma_3 \mathrm{GELCR}_t + \epsilon_t$
Model 4	Equation 4
	$\mathrm{GFDDG}_t = \beta_0 + \alpha_1\epsilon_{t-1} + \alpha_2\epsilon_{t-2} + \alpha_3\epsilon_{t-3} + \gamma_1 \mathrm{GRGDP}_t + \gamma_2 \mathrm{GATPG}_t + \gamma_3 \mathrm{GNEPGR}_t + \gamma_4 INF_t + \epsilon_t$
Model 5	Equation 5
	$\mathrm{GFDDE}_t = \beta_0 + \alpha_1\epsilon_{t-1} + \alpha_2\epsilon_{t-2} + \alpha_3\epsilon_{t-3} + \alpha_4\epsilon_{t-4} + \gamma_1 \mathrm{GRGDP}_t + \gamma_2 GTELR_t + \gamma_3 GPOP + \gamma_4 D3_t + \epsilon_t$
Model 6	Equation 6
	$\mathrm{GFDIE}_t = \beta_0 + \alpha_1\epsilon_{t-1} + \alpha_2\epsilon_{t-2} + \gamma_1 \mathrm{GRGDP}_t + \gamma_2 GGDPD_t + \gamma_3(D3 * GTELI) + \gamma_4 GTELI_t + \epsilon_t$
Model 7	Equation 7
	$GFD_t = \beta_0 + \gamma_1 \mathrm{GRGDP}_t + \gamma_2 (GGDPD_t * D3) + \gamma_3 GUSPK + \gamma_4 (GPOP_t * D3)_t + \epsilon_t$

4.2. Estimation

Model 2 take growth in final gas demand by industrial sector as dependent variable and growth in nominal GDP, growth in natural gas tariff for industrial sector growth in GDP deflator / inflation and time dummy with value 1 from 1994 to 2003 & from 2007 to 2021 taken as independent variable and 0 in other periods with second order moving average process and 1st order autoregressive process. Results from this model presents that tariff of natural gas and growth in GDP deflator/ Inflation are negatively related with demand. However, growth in nominal GDP is positively related with industrial gas demand.

Table 4
Estimation Results

GFCTO	C	GTTRD	GCGDP	GPOP	A.R.(1)	A.R.(2)	M.A.(1)	MA(2)		
ρ	-0.0339	-0.4257	0.2460	4.0017	0.6002	-0.6567	-1.9852	1.0000		
P-Value	0.0349	0.0000***	0.0000***	0.0000***	0.0015	0.0004	0.0000	0.0000		
R-squared	84%									
Adjusted R-squared	79%									
GFDIG	**C**	**GCGDP**	**GTGAI**	**GGDPD**	**D4**	**A.R.(1)**	**M.A.(1)**	**M.A.(2)**	**M.A.(3)**	**M.A.(4)**
ρ	0.0844	1.6166	-0.1202	-1.9417	-0.0804	-0.3604	-0.8194	0.4781	0.0228	-0.6815
P-Value	0.0646	0.0041***	0.1039*	0.0006***	0.0006***	0.0853	0.0000	0.0000	0.0000	0.0000
R^2	71%									
Adjusted R^2	57%									
GFCIC	**C**	**GGDPD**	**GTGACP**	**GELCR**	**A.R.(1)**	**A.R.(2)**	**A.R.(3)**	**A.R.(4)**		
ρ	-0.0139	-1.5651	-0.6019	6.5757	0.6597	-0.9621	0.7106	-0.8600		
P-Value	0.7437	0.0000***	0.0000***	0.0001***	0.0049	0.0001	0.0019	0.0002		
R^2	94%									
Adjusted R^2	88%									
GFDDG	**C**	**GRGDP**	**GATPG**	**GNEPGR**	**INF**	**M.A.(1)**	**M.A.(2)**	**M.A.(3)**		
ρ	0.0549	-0.2558	0.2495	0.0290	0.2009	2.1612	1.3225	0.1613		
P-Value	0.0000	0.0000***	0.0879**	0.0000***	0.0000***	0.0000	0.0000	0.0000		
R^2	90%									
Adjusted R^2	86%									
GFDDE	**C**	**GRGDP**	**GTELR**	**GPOP**	**D3**	**M.A.(1)**	**M.A.(2)**	**M.A.(3)**	**M.A.(4)**	
ρ	-0.2416	0.5725	0.0872	11.0962	0.0224	0.3378	0.3241	0.7454	0.5767	
P-Value	0.0577	0.0000***	0.0000***	0.0299***	0.0408***	0.0004	0.0002	0.0022	0.0015	
R^2	75%									
Adjusted R^2	67%									
GFDIE	**C**	**GRGDP**	**GGDPD**	**D3*GTELI**	**GTELI**	**M.A.(1)**	**M.A.(2)**			
ρ	0.0249	0.7068	-0.2651	-0.0520	0.0466	0.8219	-0.1781			
P-Value	0.0028	0.0001***	0.0000***	0.0238***	0.0000***	0.0000	0.0035			
R^2	74%									
Adjusted R^2	67%									
GFD	**C**	**GRGDP**	**GGDPD*D3**	**GUSPK**	**GPOP*D3**					
ρ	0.0255	0.7207	-0.3013	-0.1509	1.5912					
P-Value	0.1547	0.0210***	0.0424***	0.0743**	0.0271***					
R^2	55%									
Adjusted R^2	47%									

Note: Standard errors are reported with *(asterisk) *, **, *** indicates significance at the 90%, 95%, and 99% level, respective model 1 consist of growth in final oil consumption in transportation sector as dependent variable including independent variable including growth in domestic prices of high-speed diesel, growth in nominal GDP, growth in population. This model founds to be best fit as 84% explained with 2nd order autoregressive and moving average processes.

Model 3 consist of growth in final coal consumption by industrial sector as dependent variable and independent variables include growth in GDP deflator / inflation, growth in natural gas tariff for captive power and growth in residential electricity customers along with 4th order autoregressive process. Dependent variable is positively linked with growth in residential customers. These results are similar with the industrial gas consumption as tariff and inflation are negatively related with the coal demand in industrial sector. The model is selected as it is best fitted with the R^2 of 74.0%.

Model 4 has the R-squared value of 90% which is best fitted model include variables such as growth in final gas demand by domestic sector, growth in real GDP 2015-16, change in the access to pipeline gas connections, growth in nominal gas tariff for residential customers and inflation with 3rd order MA process. gas in real GDP is negatively linked with domestic demand

while access to gas connection, gas tariff and inflation are positively related. Interestingly this violates the law of demand but this is due to the fact that gas tariff for the domestic sector is too low which does not affect the demand for the consumer in case of change in tariff.

Model 5 include growth in final electricity demand by domestic sector, growth in real GDP 2015-16, electricity tariff growth for residential sector, increase in population, time dummy with value 1 from 2008 onwards and 0 before 2008 with 3rd order MA process. Underlying reason for selecting dummy variable in this model is due to the reason that power generation capacity expansion in 2004. The time dummy variable has taken as there were electricity power generation capacity expansion in in 2004. Surprisingly, demand for electricity in domestic sector is positively linked with its tariff however the value is two small which does not significantly change the domestic sector demand for electricity.

Model 6 is best fitted with R^2 of 74% as this model took final electricity demand growth by industrial sector, growth in real GDP 2015-16, growth in GDP deflator / inflation, time dummy with value 1 from 2008 onwards and 0 before 2008* electricity tariff growth for industrial sector, electricity tariff growth for industrial sector with 2nd order moving averages. There is negative relation with inflation and tariff with time dummy is negatively correlated however, tariff for industrial electricity is positively related with the coefficient of 0.0466. Growth in Real GDP are positively correlated.

Model 7 take final demand of energy growth by all sector as dependent and independent variable growth in real GDP 2015-16, growth in GDP deflator / inflation*time dummy with value 1 from 2008 onwards and 0 before 2008, growth in USD/PKR exchange rate and growth in population*time dummy with value 1 from 2008 onwards and 0 before 2008. The real growth in real GDP is positively related with the demand. Moreover, growth in GDP deflation with time dummy variable and growth in exchange rate is negatively related with final energy demand. Additionally, population growth with time dummy variable is positively related due to the fact that increase in population lead to increase in demand for electricity.

4.3. Diagnostic Check

Following the model specification, diagnostic checks are carried out to ensure the model's suitability for the data. Various diagnostic tests are applied to validate the models and select the most appropriate one.

Table 5
Heteroskedasticity Test: ARCH

Model	Heteroskedasticity Test: ARCH Results			
Model 1	F-statistic	0.833641	Prob. F(1,28)	0.369
	Obs*R-squared	0.867363	Prob. Chi-Square(1)	0.3517
Model 2	F-statistic	2.093511	Prob. F(1,28)	0.159
	Obs*R-squared	2.087006	Prob. Chi-Square(1)	0.1486
Model 3	F-statistic	0.001268	Prob. F(1,28)	0.9721
	Obs*R-squared	0.001463	Prob. Chi-Square(1)	0.9695
Model 4	F-statistic	0.826545	Prob. F(1,28)	0.371
	Obs*R-squared	0.860191	Prob. Chi-Square(1)	0.3537
Model 5	F-statistic	1.464281	Prob. F(1,28)	0.2364
	Obs*R-squared	1.490905	Prob. Chi-Square(1)	0.2221
Model 6	F-statistic	0.067234	Prob. F(1,28)	0.7973
	Obs*R-squared	0.071863	Prob. Chi-Square(1)	0.7886
Model 7	F-statistic	0.686644	Prob. F(1,28)	0.4143
	Obs*R-squared	0.71808	Prob. Chi-Square(1)	0.3968
Model 8	F-statistic	0.002938	Prob. F(1,28)	0.9572
	Obs*R-squared	0.003148	Prob. Chi-Square(1)	0.9553

(Source: Authors' contribution)

The diagnostic assessment involves analyzing the serial correlation of the series. In most of the models, no significant autocorrelation is detected, except for one model where weak autocorrelation is found. This level of autocorrelation is deemed acceptable, and as a result, forecasts are generated based on it.

Moreover, other measure that is applied in this is to check the model for heteroscedasticity of data. This issue incurred when standard deviation is not constant for the estimated variables and related with its lag (Wooldridge, 2015). Contrarily, null hypothesis is tested and it is rejected in case if the p-values associated with F statistics and $\chi 2$ statistics are less than the level of significance level.

According to the results presented in Table 2, the p-values are lower than the 5% significance level. This represents that the null hypothesis is accepted, and it can be concluded that the residuals are homoscedastic.

4.4. Energy Consumption in Each Sectors by Different Fuel Type

The figure provided reveals the final energy demand for various types of fuels within each sector in the year 2021. Notably, the industrial sector is the most diverse in its fuel consumption, utilizing all categories of fuels. Conversely, the residential sector relies on all types of fuels. Gas is the predominant fuel in both the domestic and industrial sectors, serving as source of energy generation for different purposes. Within the transportation sector, energy consumption primarily consists of two fuels: oil and gas. In contrast, the agriculture and commercial sectors exhibit notably lower energy usage than other sectors of energy. As of 2021, the industrial sector stands out with the highest energy demand, totaling approximately 24 million metric tons of oil equivalent (mmtoe).

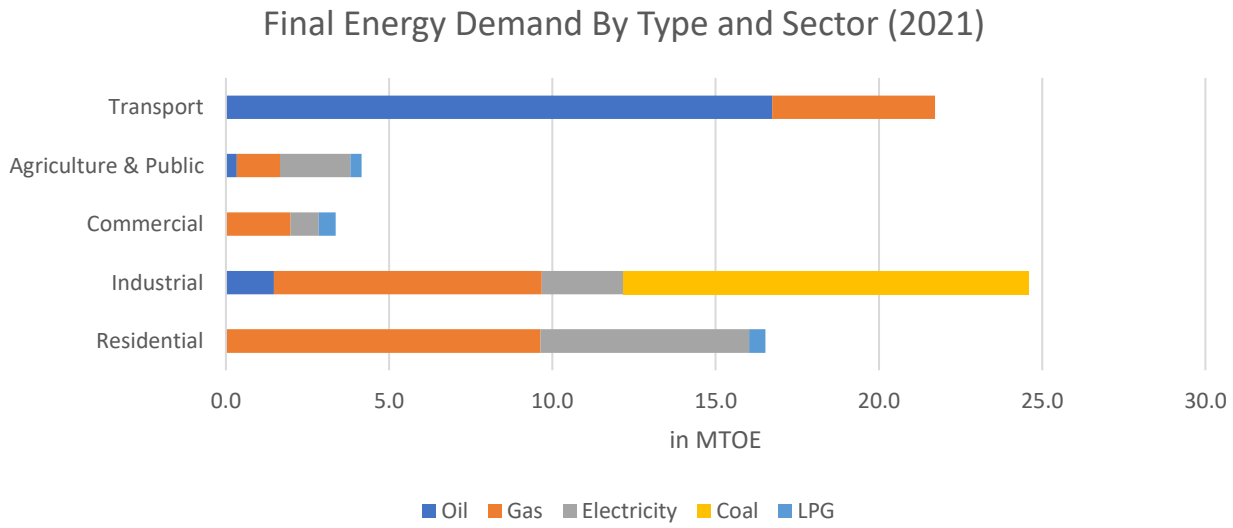

Figure 1: Energy Consumption in Each Sectors by Different Fuel Type (2021)

In contrast, Figure 1 provides a visual representation of the projected final energy demand for various fuel types within each sector. This projection anticipates a significant overall increase in energy demand across all sectors, with the relative proportions of each fuel type expected to remain stable. Notably, the industrial sector is forecasted to experience a substantial rise in overall energy demand, estimated at around 23.6%. Among the various sectors, both the industrial and residential sectors are expected to maintain their dominance in terms of increased energy demand.

4.5. Sectoral Demand Share

Energy demand has been varied significantly in each sector, dependent on the unique consumption requirements. As compared to the previous measure for the energy share transportation sector still heavily relies on oil and gas, constituting 30.9% of the total energy demand. In contrast, energy demand in industrial sector encompasses all types of fuel other than LPG, making up 34.9% of the total energy demand, with primary consumption of oil, gas, and coal. Likewise, energy demand in domestic sector includes all fuels except coal. Domestic demand is significantly dependent on gas and electricity sources that is accounted for 23.5% of the total energy demand. In contrast, the Agriculture & Public and Commercial sectors have a relatively small share in the overall energy mix, comprising 5.9% and 4.8%, respectively. It's worth noting that certain categories show zero consumption.

Table 6
Shares of Sectoral Demand for Final Energy by Type of Fuel (2021)

Sector & Type of Fuel	Share
Transport Oil	27.5%
Industrial Gas	12.9%
Domestic Gas	12.0%
Industrial Coal	20.4%
Domestic Electricity	7.9%
Industrial Oil	2.4%
Industrial Electricity	4.0%
Agriculture Electricity	3.5%
Transport Gas	2.1%
Commercial Gas	1.1%
Agriculture Oil	0.5%
Commercial Electricity	1.1%
Domestic Oil	0.1%
Domestic LPG	0.8%
Commercial LPG	0.9%
Agriculture Gas	2.2%
Agriculture LPG	0.6%
Total	100.00%

Source: Author's Calculations

Table 7
Final Energy Demand Share (2021)

Sectors	Share
Industrial	34.9%
Transport	30.9%
Residential	23.5%
Agriculture & Public	5.9%
Commercial	4.8%

Source: Author's Calculations

4.6. Discussion

Estimated results for the sectoral demand presents that major consumer of energy is industrial and residential. Industrial sector utilizes all sources of energy for its production purpose or it is used for the captive power plants. On the basis of this, industrial sector found to be an

important factor for the GDP growth of the economy. This is also confirmed from the study of (Durrani et al., 2021) that energy is an important part for the growth of the country and it is an essential element for industrial production process. Moreover, results shows that gas demand in energy sector also price dependent in industrial sector and it is used for the generation of electricity in most of the industries. Literature also emphasizes on importance of natural gas for the industrial development as it provides clean and cheap fossil fuels than other sources which make gas as more valuable than other sources (Abas et al., 2015). On the other hand, research of Rehman et al. (2017) shows that in Pakistan there is shift in industrial consumption from electricity to gas due to interrupted power supply. Therefore, other sources of energy use by industries for uninterrupted power supply. On the other hand, demand for electricity in industrial sector is affected by inflation and exchange rate as major sources of energy are import based.

Second largest consumer of energy is the residential sector which depends income, growth in population, prices and number of new connections. In this regard, study of Abas et al. (2015) reported 5.5% growth of due to usage of gas-based appliances for different purposes. Growth in final demand for domestic gas influenced by number of gas connection, gas tariff and inflation. However, law of demand violates as estimation shows the positive relation of demand with price of the product but the value is significantly low which brings no significant influence on final demand. Similar results represented for the final electricity demand in domestic sector.

Other than this, consumption of oil in transportation is negatively linked with the prices of high-speed diesel. Contrarily, Durrani et al. (2021) mentioned that transportation sector also the main consumer of gas. However, the current result shows that due to shortage of gas transportation consumption for gas has declined and the overall consumption of gas in transportation sector is only 2.1%. Study of Waheed Bhutto et al. (2017) confirms that gas consumption significantly depended on its historical trends.

Estimation for the coal in Pakistan energy outlook 2020 shows this as the Giffen goods indicates that increase price level led to increase in demand for the product (Raza et al., 2023). Contrarily, the current estimate of Demand for coal shows positive relation with the gas tariff for industrial sector. This is mainly used for the captive power. With an increase in inflation level industrial sector opt for the better and economical options for their inputs. In this regard, research of Durrani et al. (2021) identified growth in local coal project share, where total share is small but expected to rise further till 2040 by 25%.

5. Conclusion

Utilizing the Box Jenkins method, this study uncovers that energy demand in various sectors is significantly shaped by factors such as price, income, productivity, and inflation. From the analysis, it has been found that price of the energy source plays an important role for determining the demand for products. From the analysis of each source in different sectors, it has been found that there demand for the energy in different sector affected by real GDP. Notably, the industrial sector stands out as the primary consumer of energy, while residential usage is predominantly centered on gas and electricity. In the realm of transportation, oil reigns as the predominant fuel source, with a marginal contribution from gas.

A central finding of the analysis underscores a critical concern: a demand-supply gap primarily stemming from shortfalls in electricity and gas availability. Nevertheless, there is optimism that this deficit may diminish with the effective implementation of government energy supply initiatives, potentially leading to its complete eradication within the next seven years.

The study also emphasizes the current heavy reliance on fossil fuels for primary energy supply, with oil, gas, and coal collectively accounting for over 85% of energy consumption. However, there are promising prospects for a more diversified energy mix in the future. In

conclusion, it becomes evident that the residential and industrial sectors exhibit higher energy consumption rates, primarily due to restricted access in the residential sector and inefficiencies in consumption. Anticipated population growth foreshadows an increase in future energy demand and supply, although it is expected to remain relatively lower compared to global trends. Due to difference in nature and requirement of energy in each sector, demand for the energy varied significantly which is dependent on price, level of income, productivity and inflation. From the analysis, it is found that industrial energy has the higher demand which use each category of fuel except for the LPG. However, the main consumption of energy is of electricity that is price dependent which is linked with real GDP. Residential is found to be the second consumer of energy which has higher consumption of gas and electricity. Transportation demand only for fuel.

The primary challenge to the energy sector of Pakistan is demand supply gap which can be minimized by efficient government planning which will lead to attaining break-even in future. From the analysis of energy demand and supply and identifying its challenges, it recommended to government to make appropriate policy for catering the increasing need of energy. Although different plans and policy has been made but it is not found to be effective for attaining the expected outcomes. Moreover, the higher dependence on fossil fuels and imported source of energy lead to increase in import bills therefore, there is a need to implementing plan for quick conversion towards the renewable energy sources in Pakistan.

5.1. Recommendations

- To ensure the sustainability of the energy sector, there is a need to reduce the reliance on fossil fuels, lower the import bill, increase energy efficiency, and make energy affordable for consumers. Gradual retirement of oil and gas-based power plants and their maximum replacement with renewable energy is vital. There is a need to focus on indigenous resources such as coal which can be used in replacement of imported coal. Implementation of the National Electric Vehicle Policy should be a priority to promote sustainability in the transportation sector.
- The high reliance on imported energy, especially oil and gas, is a major contributor to the import bill. A multi-pronged strategy is needed to conserve energy, promote energy efficiency, explore alternative energy sources, and increase energy exploration. Failing to take definitive action in the present will only lead to a deeper energy and economic crisis in the future
- Encourage industry to innovate and produce energy efficient equipment and appliances as it will reduce the residential and industrial sector demand for energy which are expected to be the largest contributors to energy consumption.
- To ensure availability of high frequency data, so the effective measure for the future can be calculated by incorporating seasonal variation in Data.

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

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