



# Another outlook to sector-level energy consumption in Pakistan from dominant energy sources and correlation with economic growth

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## Abstract

The present study seeks to investigate the sector-level energy consumption of oil and natural gas and to explore the linkage between economic growth, households, agriculture, industry, power, fertilizers, and commercial sector in Pakistan for the period of 1980–2016. The energy sector of Pakistan is facing severe crisis from the last few years due to inadequate production and supply. Long-lasting deficits of natural gas and oil, the two supreme types of fuel in Pakistan, had detrimental consequences for the growth as well as for the economic development. An autoregressive distributed lag (ARDL) method and Granger causality test under vector error correction model (VECM) were employed to check the association among the variables. Furthermore, the innovative accounting method was used to investigate the responsiveness of each variable to another within the study framework. Empirical results show long-run association among the variables, as oil consumption in the agriculture and power sector show a positive effect on Pakistan's economic growth. Similarly, energy consumption from natural gas in the households and fertilizers as well as in the industry sector has had a constructive association with economic growth. In contrast, energy consumption from oil in the households and industry sectors has adverse association with economic growth, while natural gas consumption in the commercial sector has negative linkage with economic growth. Possible steps should be taken by the Government of Pakistan to enhance the production of oil and natural gas from other alternatives to meet the requirements of these sectors.

**Keywords** Energy consumption · Agriculture · Industry · Economic growth · ARDL · Pakistan

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## Introduction

Pakistan's energy sector has faced many challenges over the last few decades. Some of the prominent challenges in front of the sector have been related to heavy reliance on oil and natural gas. Insufficient domestic energy production coupled with dependence on domestic energy sources, the low utilization of hydrological and coal resources, the financial fragility of power companies, and power production capacity constraints led to severe energy shortages (Pakistan Energy Year Book 2009; Ali and Nitivattananon 2012). In addition, increased dependence on expensive furnaces for thermoelectric production in conjunction with international oil price volatility had a detrimental effect on the cost of electricity and "sealed the fate" of a prolonged energy crisis in Pakistan (Wasti 2015).

The population of Pakistan is increasing and energy demand is also rising with the passage of time. Furthermore, the statistics of United State Energy Information Agency outlined the positive correlation between energy power supplies in achieving sustainable economic growth in developed, emerging, or developing economy (EIA 2018). Pakistan, a developing economy with a stretching population of over 200 million inhabitants, has high demand for electricity given its swift population increase (Shahbaz and Feridun 2012). This increase is due in part to household demand and in part to a growing manufacturing sector. The manufacturing sector also has a dominant role for its economy. Experiencing electricity shortages in manufacturing has had detrimental consequences for the entire economy. This is why we argue that the development of Pakistan's energy sector requires preferential attention from the policymakers, if long-term growth and sustainability are to be achieved.

The present study does not claim to be the foremost to highlight the importance of energy as the lifeline for Pakistan's economy (Ali 2015; Ullah et al. 2017; Komal and Abbas 2015; Shaikh et al. 2016; Zhang et al. 2018; Wang et al. 2018; Zafar et al. 2018; Hassan et al. 2018; Baz et al. 2019; Luqman et al. 2019; Khan et al. 2020). Energy has versatile form as electricity that fuels the production processes of all economic sectors. The energy failure in Pakistan has led the entire national economy to perform poorly from the past few years (Aized et al. 2018). In 1980, the consumption of energy in Pakistan was 24.8 million metric tons and during the same period, energy production ratio was 20.8 million metric tons of oil equivalents. The gap between consumption and production continues to grow, and in 2011, the total consumption of energy was 20.8 million metric tons, while the output was only 65.8 million metric tons (Imran and Amir 2015).

Some analysts attribute the persistent energy supply gap, and more specifically the electricity shortages, to electricity theft and abuses, such as excessively high electrical line losses and severe weather events. In addition, there were reports of

corruption, mismanagement, and political controversy involving a project to build a giant power plant for electricity production (Zameer and Wang 2018). To address these problems and bridge the electricity supply gap, we must seek a better understanding of the root causes of the electricity crisis.

In addition to resolving the imminent electricity problems, Pakistan needs a comprehensive strategy for sustainable energy production and balanced economic development. Sustainability is now a common goal of many countries. Sustainable development requires strategies intended at firstly achieving a clean environment without influencing the economic growth and secondly increasing the reliance on energy security and renewable energy resources (Valasai et al. 2017; Malik 2012; Javid and Sharif 2016). The linkage among environmental sustainability and economic performance is tightly linked the association between energy consumption and economic growth (Pablo-Romero and De Jesús 2016; Alam et al. 2012; Narayan and Doytch 2017). Therefore, casting light on the connection amid economic growth and energy consumption in Pakistan will allow for improving the policies toward attaining the sustainable development.

The environmental policy launched in Pakistan in 2005 was directed at protecting, preserving, and restoring the environment in Pakistan for the improvement and quality of life and for supporting economic expansion. The main focus of the policy is on improving energy efficiency and resolving problems in the energy sector. The more distant goal of the policy is climate change and mitigation. The growth strategy focuses on both energy efficiency and the reduction of greenhouse gas emissions (Khan and Qayyum 2009). In the light of the global movement to combat climate change, the government of Pakistan believes that energy conservation and energy efficiency are viable strategies to fulfill the international anti-climate-change commitments (GOP 2005; Rafique and Rehman 2017).

Since the beginning of the millennium, Pakistan's energy sector has received additional consideration in order to boost the growth and energy demand. However, simultaneously with the power shortages, the country has been experiencing a number of environmental challenges, such as inadequate water supply and sanitation, air pollution, and deforestation (GOP 2012). That is why there is a need of an integrated approach to solving all of these problems simultaneously.

Pakistan is a developing economy, which differs in construction and transference technologies from its developed counterparts. In addition, Pakistan is in possession of a variety of natural resources that have the potential to enable the country to produce its own energy at low cost. These resources include hydropower, solar energy, coal, and wind (Shaikh et al. 2016; Sheikh 2010; Farooq and Shakoor 2013). At present, this potential has not been fully utilized.

Various studies have focused on the requirements of Pakistan's electricity sector (Government of Pakistan 2013;

Rehman et al. 2018; Nawaz et al. 2013) and on residential electricity consumption in the country (Hussain et al. 2016). However, there are no studies covering the link between energy consumption in other sectors including agriculture, industry, power, and economic growth, and also researchers did not test the relationship of oil energy consumption with growth, nor did they examine energy consumption by sectors. This is where our study contributes to the literature.

Currently, the main sources from which electricity is produced are oil and gas. Both have been associated with excessive production costs and high output prices (Alter and Syed 2011). The variations in the cost of electricity led to high levels of revolving debt and higher subsidies for the thermal plants that depend on fossil fuels. These complemented by mismanagement, corruption, and limited budgets are the biggest challenges in front of Pakistan's power generation (Valasai et al. 2017; Imran and Amir 2015). The complexity of the country's energy policy is exacerbated by the fact that it is carried out beneath the canopy of multiple government agencies and ministries with imperfect or no coordination. In order to tackle the problem, there are disagreements and lack of responsibility on part of the involved agencies and institutions. When we add to that the rampant power theft and system inefficiencies, including more than 25 percent of transmission and distribution damages, we get the entire picture of the problems of the Pakistan's energy sector (Jamil 2013). Government could also focus on bioenergy production by introducing microfinance programs. Renewable energy distributes the most sustainability and compatible substructure for energy. Modern technology utilization can enhance the sustainable energy production with comprising renewable sources such as hydropower, wind energy, and solar power. Many studies have been conducted to highlight the linkage of oil energy production, fossil fuel energy consumption, electrical energy, electricity access, resource rent, clean energy and environment, renewable power generation, and carbon dioxide emissions with economic growth to demonstrate the energy cause due to production and supply (Solarin and Ozturk 2016; Shaikh et al. 2016; Mirza and Kanwal 2017; Ahmed et al. 2017; Shahbaz et al. 2017; Rehman and Deyuan 2018a, b; Ashfaq and Ianakiev 2018; Nawaz and Alvi 2018; Rehman et al. 2018; Rehman et al. 2019; Chandio et al. 2019a; Chandio et al. 2019b; Naz et al. 2019; Dogan et al. 2019; Ozcan et al. 2019; Bekun et al. 2019a, 2019b; Rehman et al. 2020; Usman et al. 2020).

It is on the above premise highlighted that this study is conducted to demonstrate the oil and natural gas consumption in the households, agriculture, industry, power, fertilizers, and commercial sector in a holistic manner for the case of Pakistan for the period of 1980–2016. To drive down the above motivation, conventional unit root test of Augmented Dickey–Fuller (ADF) is used to check the stationarity properties of the outlined variables with trend and intercept.

Subsequently, autoregressive distributed lag (ARDL) bounds testing approach and Granger causality test under vector error correction model (VECM) context in conjunction with an innovative accounting method, to explore the associations among the study variables, is used. Studies of this sort are worthwhile and timely for the study area and current body of knowledge, especially in the current way of crusade for alternative energy sources that is ecosystem friendly and safe.

## Oil and natural gas energy consumption in Pakistan during 1980–2016

The extent to which Pakistan's economy is negotiated by energy price shocks relay on oil share and the rate at which energy demand has been increasing parallel to economic growth (Economic Survey of Pakistan 2006; Zakaria and Noureen 2016). During 2006–2007 censuses, about 44% of Pakistan's export earnings have been spent on imported oil. This is a sharp increase from 28% in 2004–2005. As a result of the large oil share on the country's energy mix, any global oil price fluctuations directly affected national macroeconomic conditions. The imports of oil increased from 3.13% in 1990–1991 to 5.24% in 2005–2006 as the share of Pakistan's gross domestic product. The decline in the energy concentration is measured to be the most promising way to reduce the susceptibility to oil (Malik et al. 2007; Bala and Chin 2018). The oil consumption in different sectors is showed in Fig. 1.

Figure 1 indicates the oil consumption in different sectors including households, agriculture, industry, and power sector from 1980 to 2016. This time span data from 1980 to 2016 was taken from the Economic Survey of Pakistan.

Figure 2 represents the natural gas consumption in the households, fertilizers, and industry and commercial sectors respectively over study period.

Natural gas is a dominant and an essential energy source that is used to produce electricity. To meet the Kyoto Protocol CO<sub>2</sub> targets, many countries explore the possibilities of moving to natural gas as an alternative to oil. Developing countries like Pakistan are unlikely to entice investment to build expensive new energy infrastructure, so natural gas is seen as a more affordable substitute for oil-based energy. The natural gas accounts for approximately about 47% of key demand in the country. Oil and natural gas are representing 20% and 50% of the total energy consumption and are major foundations of energy in Pakistan, respectively (Apergis and Payne 2010; Pakistan Energy Year Book 2005; Shahbaz et al. 2014). Some research studies are conducted in Pakistan and in other countries to demonstrate the economic growth conjunction with energy policy, energy consumption, environmental challenges, coal consumption, and renewable energy production (Kumar and Shahbaz 2012; Khan

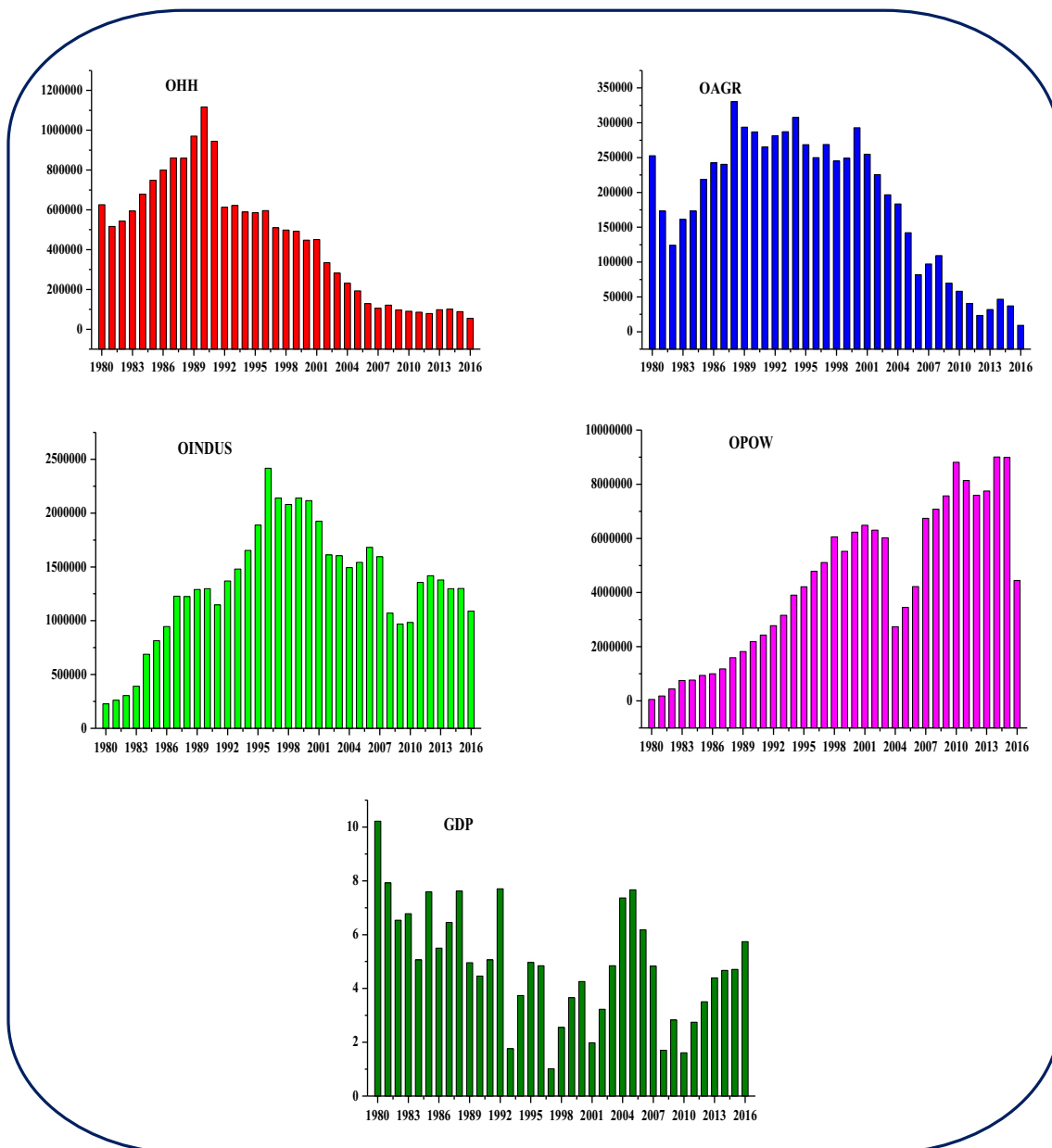


Fig. 1 Oil consumption variable trends

and Qayyum 2009; Imran and Siddiqui 2010; Rafindadi and Ozturk 2015; Kamran 2018; Balsalobre-Lorente et al. 2019; Rauf et al. 2018; Bekun et al. 2019b; Udi et al. 2020; Rauf et al. 2020). The natural gas energy consumption in different sectors is showed in Fig. 2.

## Methodology and data

### Data sources

Time series data was used in this paper to explore the association amid variables, and the range of data is

from 1980 to 2016. The variables used in this study in terms of oil consumption in various sectors are gross domestic product (annual), oil consumption in households (tons), oil consumption in agriculture sector (tons), oil consumption in industry (tons), and oil consumption in power sector (tons). Similarly, variables used for gas energy consumptions are gas consumption in households (mm cft), gas consumption in fertilizers (mm cft), gas consumption in industry (mm cft), and gas consumption in commercial (mm cft). The data major sources are World Development Indicators (WDI) and Economic Survey of Pakistan.

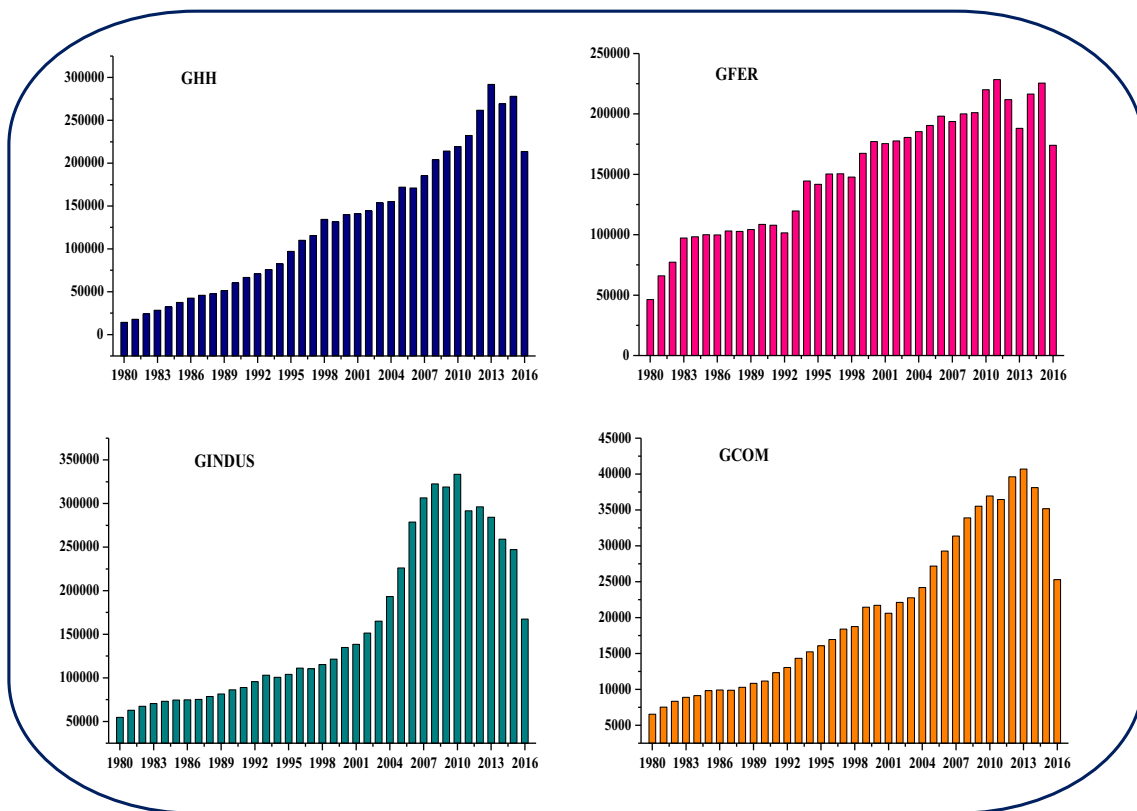


Fig. 2 Natural gas consumption variable trends

**Econometric model specification**

To demonstrate the association between the variables, we will specify the model separately for both oil and natural gas consumption.

a. Model specification for oil consumption in various sectors

For oil energy consumption in households, agriculture, industry, and power sector, the following model is specified as:

$$GDP_t = f(OHH_t, OAGR_t, OINDUS_t, OPOW_t) \tag{1}$$

In Eq. (1),  $GDP_t$  indicates the gross domestic product,  $OHH_t$  represents the oil consumption in households,  $OAGR_t$  indicates the oil consumption in agriculture,  $OINDUS_t$  represents the oil consumption in the industry sector, and  $POW_t$  indicates the oil consumption in power sector. We can also write Eq. (1) as:

$$GDP_t = \gamma_0 + \gamma_1 OHH_t + \gamma_2 OAGR_t + \gamma_3 OINDUS_t + \gamma_4 OPOW_t + \mu_t \tag{2}$$

Equation (2) can also be written as in its logarithm form as follows:

$$\ln GDP_t = \gamma_0 + \gamma_1 \ln OHH_t + \gamma_2 \ln OAGR_t + \gamma_3 \ln OINDUS_t + \gamma_4 \ln OPOW_t + \mu_t \tag{3}$$

Equation (3) is the log-linear form of variables, where  $t$  demonstrates the time dimension,  $\mu_t$  is error term, and model coefficients  $\gamma_1$  to  $\gamma_4$  signify the long-run elasticity.

b. Model specification for gas consumption various sectors

For gas consumption in the households, fertilizers, industries and commercial sector, the following model is specified as:

$$GDP_t = f(GHH_t, GFER_t, GINDUS_t, GCOM_t) \tag{4}$$

In Eq. (4),  $GDP_t$  indicates the gross domestic product,  $GHH_t$  represents the gas consumption in households,  $GFER_t$  indicates the gas consumption in fertilizers,  $GINDUS_t$  represents the gas consumption in industry sector, and  $GCOM_t$  indicates the gas consumption in commercial sector. We can also write Eq. 4 as:

$$GDP_t = \phi_0 + \phi_1 GHH_t + \phi_2 GFER_t + \phi_3 GINDUS_t + \phi_4 GCOM_t + \varepsilon_t \tag{5}$$

**Table 1** Descriptive statistics

Oil consumption in various sectors					
	LnGDP	LnOHH	LnOAGR	LnOINDUS	LnOPOW
Mean	1.471673	12.70229	11.87167	13.98415	14.88662
Median	1.578220	13.12026	12.29630	14.11964	15.25510
Maximum	2.323926	13.92606	12.70810	14.69774	16.01341
Minimum	0.014293	10.92491	9.134500	12.33537	10.82953
Std. Dev.	0.522840	0.908416	0.870089	0.572261	1.163305
Skewness	- 0.893735	- 0.532769	- 1.377464	- 1.569555	- 1.631230
Kurtosis	3.349388	1.758348	4.173617	4.932692	5.679553
Jarque-Bera	5.113900	4.127152	13.82414	20.95019	27.47813
Probability	0.077541	0.126999	0.000996	0.000028	0.000001
Sum	54.45189	469.9847	439.2519	517.4137	550.8050
Sum Sq. Dev.	9.841006	29.70792	27.25400	11.78938	48.71800
Observations	37	37	37	37	37
Natural gas consumption in various sectors					
	LnGDP	LnGHH	LnGFER	LnGINDUS	LnGCOM
Mean	1.471673	11.73037	11.96804	11.81409	9.749728
Median	1.578220	11.78795	12.07478	11.65486	9.738613
Maximum	2.323926	14.53562	12.74322	12.71742	10.61371
Minimum	0.014293	8.566825	11.48564	10.90909	8.786151
Std. Dev.	0.522840	1.307093	0.317240	0.569354	0.545935
Skewness	- 0.893735	0.283869	- 0.078238	0.271415	0.073301
Kurtosis	3.349388	3.225345	2.302602	1.667669	1.747777
Jarque-Bera	5.113900	0.575206	0.787557	3.190896	2.450564
Probability	0.077541	0.750059	0.674503	0.202818	0.293675
Sum	54.45189	434.0235	442.8175	437.1214	360.7399
Sum Sq. Dev.	9.841006	61.50575	3.623092	11.66991	10.72962
Observations	37	37	37	37	37

The log-linear model can be specified by employing natural logarithm to Eq. (5):

$$\begin{aligned}
 \ln GDP_t = & \phi_0 + \phi_1 \ln GHH_t + \phi_2 \ln GFER_t \\
 & + \phi_3 \ln GINDUS_t + \phi_4 \ln GCOM_t + \varepsilon_t \quad (6)
 \end{aligned}$$

Equation (6) shows the logarithmic form of variables, where  $t$  is the time dimension,  $\varepsilon_t$  demonstrates the error term, and the model coefficients  $\phi_1$  to  $\phi_4$  indicate the long-run elasticity.

**Estimation of empirical analysis**

**Stationarity procedure**

Autoregressive distributed lag (ARDL) bounds testing approach does not require the stationarity of the variables through unit root test. We started the analysis with an Augmented Dickey and Fuller (1979) unit root test, and the ARDL approach is invalid in the second order. None of variables are integrated of second order.

**Table 2** Augmented Dickey–Fuller unit root test results (trend and intercept)

Variables	At level	First difference
For oil consumption in various sectors		
LnGDP	- 2.576754	- 5.655910***
LnOHH	- 2.471519	- 4.343428***
LnOAGR	0.022965	- 5.917711***
LnOINDUS	- 2.644775	- 4.486568***
LnOPOW	- 4.834421***	- 4.778990***
For gas consumption in various sectors		
LnGDP	- 2.576754	- 5.655910***
LnGHH	- 2.378975	- 5.556337***
LnGFER	- 6.275385***	- 6.068863***
LnGINDUS	- 2.915933	- 7.800406***
LnGCOM	- 0.838238	- 4.078198**

\*\* and \*\*\* denote the null hypothesis rejection of unit root at the 5% and 10% significant level respectively



Therefore, we will perform ADF unit root test below in Eq. (7):

$$\Delta Y_t = \alpha_0 + \beta_0 T + \beta_1 Y_{t-1} + \sum_{i=1}^m \alpha_i \Delta Y_{t-i} + \mu_t \tag{7}$$

In this equation,  $Y$  is the variable that will be tested for unit root,  $T$  is the linear trend,  $\Delta$  is the first difference, the time subscript is denoted by  $t$ ,  $\mu_t$  is a normally distributed stochastic error, and  $m$  represents the number of white noise residuals.

### ARDL model specification and cointegration test

The association amid study variables can be illustrated through long-run and short-run and used to examine the co-movement amid dependent and independent variables. ARDL model was first estimated by Pesaran and Shin (1998) and Pesaran et al. (2001). Cointegration test techniques was employed regardless variables orders of zero, one, and furthermore in the order of two existence. Generally, ARDL model can be specified amid variables for oil consumption as:

$$\begin{aligned} \Delta \ln GDP_t = & \vartheta_0 + \sum_{i=1}^C \vartheta_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^V \vartheta_{2i} \Delta \ln OHH_{t-i} \\ & + \sum_{i=1}^B \vartheta_{3i} \Delta \ln OAGR_{t-i} \\ & + \sum_{i=1}^X \vartheta_{4i} \Delta \ln OINDUS_{t-i} \\ & + \sum_{i=1}^Q \vartheta_{5i} \Delta \ln OPOW_{t-i} + \psi_1 \ln GDP_{t-1} \\ & + \psi_2 \ln OHH_{t-1} + \psi_3 \ln OAGR_{t-1} \\ & + \psi_4 \ln OINDUS_{t-1} + \psi_5 \ln OPOW_{t-1} + \mu_t \end{aligned} \tag{8}$$

In Eq. (8),  $\Delta$  represents the difference operator and  $C, V, B, X,$  and  $Q$  indicate the lags order. The co-movement of the long-run analysis among the interest of the variables relies on the estimation of  $F$  statistic. The analysis of long-run linkage is inspected with the autoregressive distributed lag (ARDL) depiction and specified as amid the variables:

$$\begin{aligned} \Delta \ln GDP_t = & \phi_0 + \sum_{i=1}^N \phi_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^G \phi_{2i} \Delta \ln OHH_{t-i} \\ & + \sum_{i=1}^B \phi_{3i} \Delta \ln OAGR_{t-i} \\ & + \sum_{i=1}^E \phi_{4i} \Delta \ln OINDUS_{t-i} \\ & + \sum_{i=1}^X \phi_{5i} \Delta \ln OPOW_{t-i} + \mu_t \end{aligned} \tag{9}$$

In Eq. (9),  $N, G, B, E,$  and  $X$  show the lags order. Similarly, the analysis of short-run among study variables can be demonstrated by following unrestricted error correction model (UECM) and specified in Eq. (10):

$$\begin{aligned} \Delta \ln GDP_t = & \alpha_0 + \sum_{i=1}^Z \alpha_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^S \alpha_{2i} \Delta \ln OHH_{t-i} \\ & + \sum_{i=1}^F \alpha_{3i} \Delta \ln OAGR_{t-i} \\ & + \sum_{i=1}^D \alpha_{4i} \Delta \ln OINDUS_{t-i} \\ & + \sum_{i=1}^T \alpha_{5i} \Delta \ln OPOW_{t-i} + \alpha ECM_{t-1} + \mu_t \end{aligned} \tag{10}$$

Equation (10) shows the short-run linkage amid study variables and  $Z, S, F, D,$  and  $T$  denote the lags order.

Repeating the econometric analysis for the natural gas consumption with economic growth in several sectors, the ARDL model can be specified as:

$$\begin{aligned} \Delta \ln GDP_t = & \partial_0 + \sum_{i=1}^P \partial_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^H \partial_{2i} \Delta \ln GHH_{t-i} \\ & + \sum_{i=1}^J \partial_{3i} \Delta \ln GFER_{t-i} \\ & + \sum_{i=1}^Z \partial_{4i} \Delta \ln GINDUS_{t-i} \\ & + \sum_{i=1}^C \partial_{5i} \Delta \ln GCOM_{t-i} + \beta_1 \ln GDP_{t-1} \\ & + \beta_2 \ln GHH_{t-1} + \beta_3 \ln GFER_{t-1} \\ & + \beta_4 \ln GINDUS_{t-1} + \beta_5 \ln GCOM_{t-1} + \varepsilon_t \end{aligned} \tag{11}$$

In this equation,  $\Delta$  represents the difference operator, and  $P, H, J, Z,$  and  $C$  indicate order of lags. Long-run estimation among study variables is given as in Eq. (12):

$$\begin{aligned} \Delta \ln GDP_t = & \lambda_0 + \sum_{i=1}^B \lambda_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^S \lambda_{2i} \Delta \ln GHH_{t-i} \\ & + \sum_{i=1}^H \lambda_{3i} \Delta \ln GFER_{t-i} \\ & + \sum_{i=1}^Q \lambda_{4i} \Delta \ln GINDUS_{t-i} \\ & + \sum_{i=1}^U \lambda_{5i} \Delta \ln GCOM_{t-i} + \varepsilon_t \end{aligned} \tag{12}$$

In Eq. (12),  $B, S, H, Q,$  and  $U$  represent the lags order. Furthermore, the short-run analysis in the context of natural gas consumption amid study variables can be illustrated by following unrestricted error correction model (UECM) and specified in Eq. (13):

**Table 3** ARDL bounds test for cointegration results

F statistic	Significance level	Lower bound	Upper bound	Decision
ARDL bounds test for cointegration results for oil consumption in various sectors				
5.110806	10%	2.45	3.52	Co-integrated
	5%	2.86	4.01	
	1%	3.74	5.06	
ARDL bounds test for cointegration results for gas consumption in various sectors				
6.054748	10%	2.45	3.52	Co-integrated
	5%	2.86	4.01	
	1%	3.74	5.06	

$$\begin{aligned} \Delta \ln GDP_t = & \delta_0 + \sum_{i=1}^T \delta_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^R \delta_{2i} \Delta \ln GHH_{t-i} \\ & + \sum_{i=1}^E \delta_{3i} \Delta \ln GFER_{t-i} \\ & + \sum_{i=1}^W \delta_{4i} \Delta \ln GINDUS_{t-i} \\ & + \sum_{i=1}^Q \delta_{5i} \Delta \ln GCOM_{t-i} + \alpha ECM_{t-1} + \varepsilon_t \end{aligned} \quad (13)$$

In Eq. (13), *T*, *R*, *E*, *W*, and *Q* demonstrate the lags order.

**Granger causality test under vector error correction model context**

The actions formalized above examine only for the presence of long-run and short-run nexus among the subjected variables under autoregressive distributed lag (ARDL) bound testing approach, where it does not direct the tendency of causality among study variables. Hence, as soon as the cointegrating

bonding (if any) is extant, the succeeding phase is to scrutinize the Granger’s causality examination in those variables. This test observes the contributory effect amid variables by investigating for their expectedness grounded on historical and current values. With the intention of identifying the path of causality, we will evaluate the short-run Granger causality via vector error correction model (VECM) context (Engle and Granger 1987). If the study variables in this regard cointegrated in long-run nexus under ARDL or VECM of if any, then error correction term (ECT) examined in the short run. The model amid oil consumption, natural gas consumption, and economic growth can be embodied by:

$$\begin{bmatrix} \Delta GDP_t \\ \Delta OHH_t \\ \Delta OAGR_t \\ \Delta OINDUS_t \\ \Delta OPOW_t \end{bmatrix} = \begin{bmatrix} \pi_1 \\ \pi_2 \\ \pi_3 \\ \pi_4 \\ \pi_5 \end{bmatrix} + \begin{bmatrix} \hat{\partial}_{11,1} \hat{\partial}_{12,1} \hat{\partial}_{13,1} \hat{\partial}_{14,1} \hat{\partial}_{15,1} \\ \hat{\partial}_{21,1} \hat{\partial}_{22,1} \hat{\partial}_{23,1} \hat{\partial}_{24,1} \hat{\partial}_{25,1} \\ \hat{\partial}_{31,1} \hat{\partial}_{32,1} \hat{\partial}_{33,1} \hat{\partial}_{34,1} \hat{\partial}_{35,1} \\ \hat{\partial}_{41,1} \hat{\partial}_{42,1} \hat{\partial}_{43,1} \hat{\partial}_{44,1} \hat{\partial}_{45,1} \\ \hat{\partial}_{51,1} \hat{\partial}_{52,1} \hat{\partial}_{53,1} \hat{\partial}_{54,1} \hat{\partial}_{55,1} \end{bmatrix}$$

**Table 4** Johansen cointegration test results (trace)

Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
For oil consumption in various sectors				
None*	0.655491	88.14611	69.81889	0.0009
At most 1*	0.574376	50.84885	47.85613	0.0255
At most 2	0.343341	20.95185	29.79707	0.3606
At most 3	0.106750	6.231187	15.49471	0.6682
At most 4	0.063068	2.280072	3.841466	0.1310
For natural gas consumption in various sectors				
None*	0.643894	84.22865	69.81889	0.0023
At most 1*	0.502878	49.12274	47.85613	0.0378
At most 2	0.359104	25.35948	29.79707	0.1490
At most 3	0.244529	10.23326	15.49471	0.2632
At most 4	0.020355	0.699197	3.841466	0.4031

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level, \* denotes rejection of the hypothesis at the 0.05 level, \*\*MacKinnon-Haug-Michelis (1999) *p* values



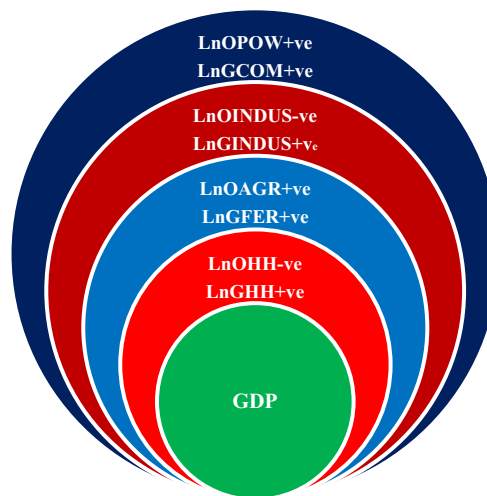
**Table 5** Johansen cointegration test results (maximum eigenvalue)

Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 critical value	Prob.**
For oil consumption in various sectors				
None*	0.643894	35.10590	33.87687	0.0355
At most 1	0.502878	23.76327	27.58434	0.1432
At most 2	0.359104	15.12622	21.13162	0.2802
At most 3	0.244529	9.534062	14.26460	0.2444
At most 4	0.020355	0.699197	3.841466	0.4031
For natural gas consumption in various sectors				
None*	0.655491	37.29726	33.87687	0.0188
At most 1*	0.574376	29.89699	27.58434	0.0248
At most 2	0.343341	14.72067	21.13162	0.3090
At most 3	0.106750	3.951115	14.26460	0.8645
At most 4	0.063068	2.280072	3.841466	0.1310

$$\begin{aligned}
 & \begin{bmatrix} \Delta GDP_{t-1} \\ \Delta OHH_{t-1} \\ \Delta OAGR_{t-1} \\ \Delta OINDUS_{t-1} \\ \Delta OPOW_{t-1} \end{bmatrix} + \dots \\
 & + \begin{bmatrix} \partial_{11,k} \partial_{12,k} \partial_{13,k} \partial_{14,k} \partial_{15,k} \\ \partial_{21,k} \partial_{22,k} \partial_{23,k} \partial_{24,k} \partial_{25,k} \\ \partial_{31,k} \partial_{32,k} \partial_{33,k} \partial_{34,k} \partial_{35,k} \\ \partial_{41,k} \partial_{42,k} \partial_{43,k} \partial_{44,k} \partial_{45,k} \\ \partial_{51,k} \partial_{52,k} \partial_{53,k} \partial_{54,k} \partial_{55,k} \end{bmatrix} \\
 & \begin{bmatrix} \Delta GDP_{t-k} \\ \Delta OHH_{t-k} \\ \Delta OAGR_{t-k} \\ \Delta OINDUS_{t-k} \\ \Delta OPOW_{t-k} \end{bmatrix} + \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{bmatrix} \\
 & \begin{bmatrix} \Delta GDP_t \\ \Delta GHH_t \\ \Delta GAGR_t \\ \Delta GINDUS_t \\ \Delta GCOM_t \end{bmatrix} = \begin{bmatrix} \pi_1 \\ \pi_2 \\ \pi_3 \\ \pi_4 \\ \pi_5 \end{bmatrix} + \begin{bmatrix} \partial_{11,1} \partial_{12,1} \partial_{13,1} \partial_{14,1} \partial_{15,1} \\ \partial_{21,1} \partial_{22,1} \partial_{23,1} \partial_{24,1} \partial_{25,1} \\ \partial_{31,1} \partial_{32,1} \partial_{33,1} \partial_{34,1} \partial_{35,1} \\ \partial_{41,1} \partial_{42,1} \partial_{43,1} \partial_{44,1} \partial_{45,1} \\ \partial_{51,1} \partial_{52,1} \partial_{53,1} \partial_{54,1} \partial_{55,1} \end{bmatrix} \\
 & \begin{bmatrix} \Delta GDP_{t-1} \\ \Delta GHH_{t-1} \\ \Delta GAGR_{t-1} \\ \Delta GINDUS_{t-1} \\ \Delta GCOM_{t-1} \end{bmatrix} + \dots \\
 & + \begin{bmatrix} \partial_{11,k} \partial_{12,k} \partial_{13,k} \partial_{14,k} \partial_{15,k} \\ \partial_{21,k} \partial_{22,k} \partial_{23,k} \partial_{24,k} \partial_{25,k} \\ \partial_{31,k} \partial_{32,k} \partial_{33,k} \partial_{34,k} \partial_{35,k} \\ \partial_{41,k} \partial_{42,k} \partial_{43,k} \partial_{44,k} \partial_{45,k} \\ \partial_{51,k} \partial_{52,k} \partial_{53,k} \partial_{54,k} \partial_{55,k} \end{bmatrix} \tag{14}
 \end{aligned}$$

**Table 6** Results of long-run analysis

Regressors	Coefficients	Std. error	T ratio	P value
For oil consumption in various sectors				
Dependent variable is lnGDP				
LnOHH	- 0.594407	0.248449	- 2.392475	0.0237
LnOAGR	16.667873	2.845875	5.856854	0.0000
lnOINDUS	- 0.001983	0.333676	- 0.005944	0.9953
LnOPOW	7.329332	1.363110	5.376919	0.0000
Constant	7.138301	2.521557	2.830910	0.0085
For natural gas consumption in various sectors				
Dependent variable is lnGDP				
lnGHH	0.684650	0.149674	4.574284	0.0001
lnGFER	0.160628	0.356651	0.450380	0.6560
lnGINDUS	1.466736	0.507263	2.891469	0.0075
lnGCOM	- 3.234583	0.704321	- 4.592480	0.0001
Constant	5.835719	2.970624	1.964475	0.0598



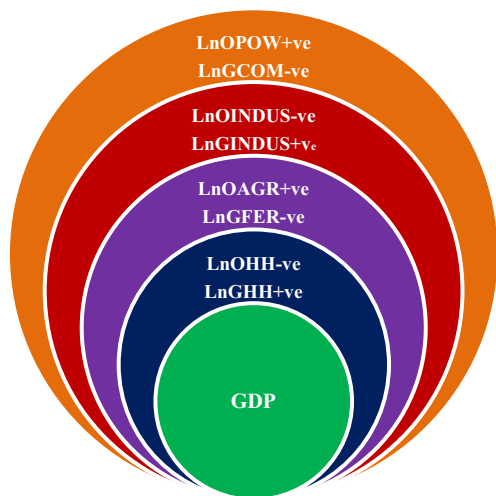
**Fig. 3** Long-run dynamics linkage among variables

**Table 7** Results of short-run analysis

Regressors	Coefficient	Std. error	T ratio	P value
For oil consumption in various sectors				
Dependent variable is lnGDP				
Δ LnOHH	- 0.612376	0.525561	- 1.165186	0.2538
Δ LnOAGR	8.204966	0.276424	29.682541	0.0000
Δ LnOINDUS	- 0.001972	0.331705	- 0.005946	0.9953
Δ LnOPOW	7.287997	0.238057	30.614541	0.0000
ECM (- 1)	- 0.994360	0.166923	- 5.957000	0.0000
R-squared	0.529581	Durbin-Watson stat 1.907130		
Adjusted R-squared	0.411976	F statistic 4.503052(0.001820)		
For natural gas consumption in various sectors				
Dependent variable is lnGDP				
Δ LnGHH	0.470453	0.230753	2.038769	0.0514
Δ LnGFER	- 0.325681	0.582996	- 0.558633	0.5810
Δ LnGINDUS	4.675520	1.391968	3.358928	0.0023
Δ LnGCOM	- 3.789645	1.109683	- 3.415070	0.0020
ECM (- 1)	- 1.171603	0.197686	- 5.926587	0.0000
R-squared	0.531652	Durbin-Watson stat 2.280583		
Adjusted R-squared	0.392882	F statistic 3.831182 (0.003993)		

$$\begin{bmatrix} \Delta GDP_{t-k} \\ \Delta GHH_{t-k} \\ \Delta GAGR_{t-k} \\ \Delta GINDUS_{t-k} \\ \Delta GCOM_{t-k} \end{bmatrix} + \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{bmatrix}$$

For oil and natural gas consumption, granger causality under vector error correction model has been demonstrated in Eqs. (14) and (15), where Δ indicates the symbolization as a difference operator, and residual term represented with λ; however, error correction term (ECT) stances the long-run association assessment and θ, the coefficient of error (ECT<sub>t</sub>–



**Fig. 4** Short-run dynamics linkage among variables

1) term in Eq. (14). If θ is arithmetically significant and negative, then it designates that the long-run underlying nexus is associated amid variables by employing t statistics. To examine the short-run granger contributory linkages, we pointed toward the F statistic grounded on Wald statistics. For instance, 12, k ≠ 0∀k suggests that oil consumption in households has granger cause toward gross domestic product.

## Empirical results and discussion

### Descriptive statistics results

Descriptive statistics results of oil consumption in households, agriculture, and power sector and in terms of gas consumption in households, fertilizer, industry, and commercial sector are interpreted in Table 1. Descriptive statistics result show that all variables are normally distributed and estimated by the Jarque-Bera statistics and probability values.

### Augmented Dickey–Fuller unit root test results

Augmented Dickey–Fuller (ADF) unit root test results are reported in Table 2.

### Cointegration test results

The cointegration test results with ARDL bounds test are showed in Table 3.

Table 3 demonstrates the presence of a cointegration linkage amid variables at the level of 10%, 5%, and 1%. Furthermore, Tables 4 and 5 illustrate the results of the Johansen cointegration test (Johansen and Juselius 1990) with trace statistics and maximum eigenvalue.

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level; \* denotes rejection of the hypothesis at the 0.05 level; \*\*MacKinnon-Haug-Michelis (1999) p values

Table 4 and Table 5 represent the Johansen cointegration test results amid the study variables.

### Results evidence of long-run

The long-run evidence results for oil consumption and gas consumption in the households, agriculture, industries, power sector, fertilizers, and commercial sector are illustrated in Table 6.

The regression coefficients of the model reveal that oil consumption in the households’ and industry sector is drastically negatively related to economic growth. It has a coefficient of - 0.594407 and - 0.001983 meaning that oil consumption in the households’ and industry has a non-significant influence to economic growth. On the contrary, the oil consumption in the agriculture and power sector shows

**Table 8** Stability and diagnostic tests results

For oil consumption in various sectors		For gas consumption in various sectors	
Test statistics (LM version)	Prob.	Test statistics (LM version)	Prob.
Serial correlation	0.5216	Serial correlation	0.1671
Heteroscedasticity	0.7321	Heteroscedasticity	0.8121
CUSUM	Stable	CUSUM	Stable
CUSUMSQ	Stable	CUSUMSQ	Stable

a significant long-run linkage with economic growth with coefficients of 16.667873 and 7.329332, respectively. Therefore, the oil consumption in the power and agriculture sectors is significantly connected to the economic growth in the long-run. Oil imports in the developing countries are severely exaggerated by increasing oil prices due to variations in the oil prices. In addition, the developed and advanced economies have a higher tax share in the oil. The interruption in the tax share caused when prices of oil rise can alleviate this oil price tremor (Chaudhry et al. 2012). Sustainable energy production and supply is an imperative factor in the sustained economic performance for any society. Pakistan belongs to those developing countries that are facing energy crisis. The country’s current and past government has premeditated numerous energy strategies to meet energy needs but fails to fill this gap (Aized et al. 2018).

Similarly, the natural gas consumption by the households, agriculture, and industry sector demonstrated a positive long-run association with economic growth. Natural gas consumption at 1% increase by households upsurses the economic growth by 0.684%, which shows a 1% increase in natural gas consumption for fertilizer production and for industrial activities increases the economic growth respectively by 0.16% and by 1.466%. Shahbaz et al.’s (2013) study on natural gas consumption and economic growth also revealed the analysis of long-run conjunction among the variables (Shahbaz et al. 2013). However, on the contrary, 1% increases

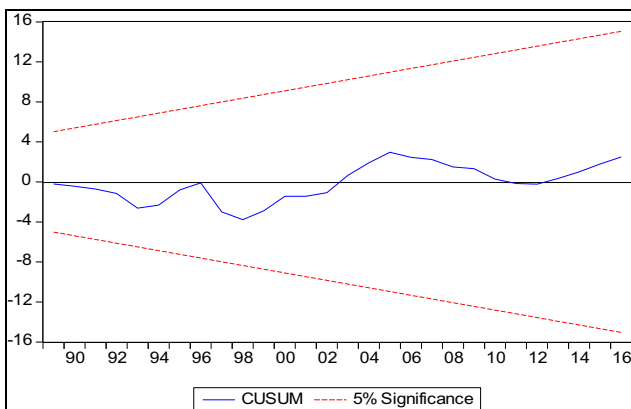
in the natural gas consumption by the power sector diminishes the economic growth – 3.235%.

Figure 3 reveals the dynamic linkage among the study variables for both oil and gas consumption in various sectors. Long-run dynamic association amid variables demonstrate that oil consumption in the household has negative linkage but gas consumption in household showed a positive linkage with economic growth. Oil consumption in the agriculture sector and gas consumption in the fertilizers showed a positive association with economic growth. Similarly, oil consumption in the industry sector has negative association whiles gas consumption in the industry exposed a positive linkage. Furthermore, oil consumption in the power sector and gas consumption in the commercial sectors has positive linkage with economic growth.

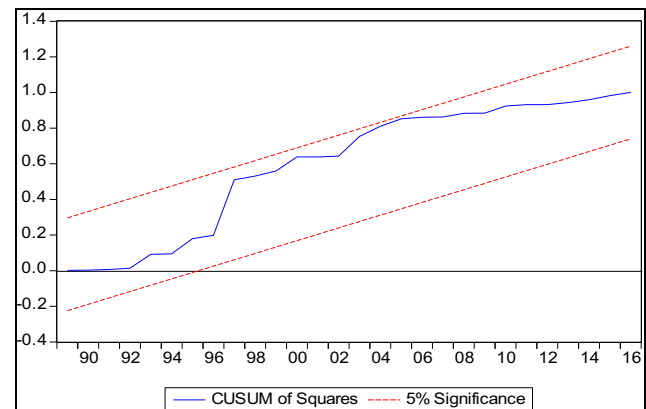
**Results evidence of short run**

Table 7 demonstrates the results evidence of short-run.

The estimated model shows the short-run dynamics, and the R-squared value is about 0.53, which means 0.53 variations in the reliant variable clarified by the independent variables. The Durbin-Watson statistic value is 1.907, which is not showing actual value of Durbin-Watson and demonstrates the autocorrelation of the non-appearance of any autocorrelation, but it is sufficient to illustrate the existence. The short-run analysis results show that oil consumption by the agricultural and power sectors has positive linkage with economic growth.



**Fig. 5** Plot of CUSUM test (oil)



**Fig. 6** Plot of CUSUM of squares test (oil)

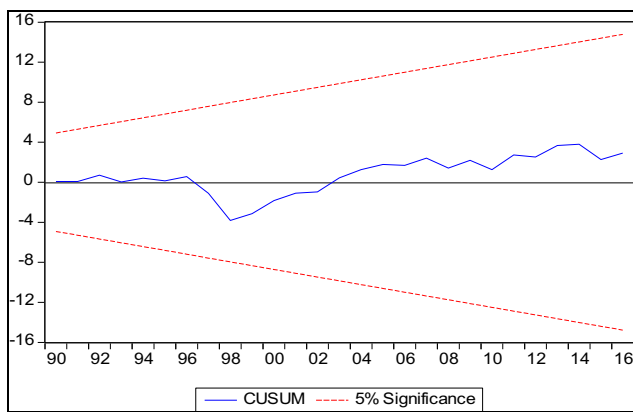


Fig. 7 Plot of CUSUM test (gas)

At the same time, oil consumption by the households and industry sectors does not show evidence of significant short-run relations with economic growth. The energy policy of Pakistan should be directed at efficient use of oil and natural gas, extraction infrastructure, and technology development. Solar electricity and bioenergy are other important alternatives. In addition, bioenergy has emerged as a viable source of renewable energy and also has a tremendous potential to meet the country's energy needs (Shahbaz et al. 2014; Kamran 2018; Irfan et al. 2020).

When the natural gas consumption is analyzed, the short-run dynamics show that the model explains about 53% variations in the economic growth. The value of the DW statistic is 2.28 which demonstrate the non-existence of autocorrelation. The coefficients reveal a positive short-run connection of natural gas consumption by households and industry with economic growth, and a negative relationship of the natural gas consumption by the fertilizers production and power sectors with economic growth.

Figure 4 illustrates the dynamic association of variables through short-run analysis. Results exposed that oil consumption in household has negative association with economic growth and gas consumption in household demonstrate a significant linkage to economic growth in Pakistan. Similarly, oil

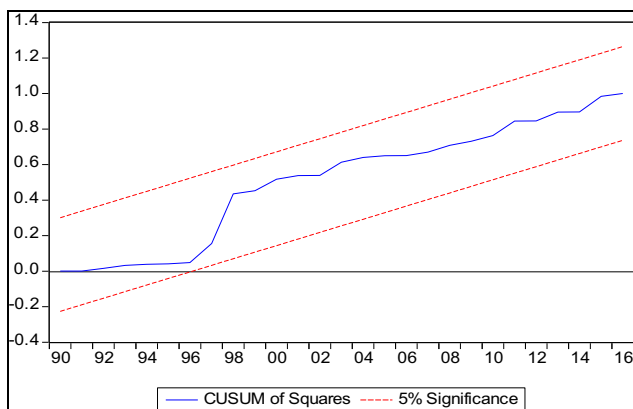


Fig. 8 CUSUM of squares test (gas)

consumption in agriculture sector has positive linkage while gas consumption in fertilizers has negative linkage with economic growth. Results also exposed that oil consumption in industry sector have negative linkage while gas consumption in industry sector has positive linkage with economic growth. Furthermore, short-run analysis also exposed that oil consumption in power sector has positive linkage while gas consumption in commercial sector negative linkage with economic growth.

## Diagnostic and stability tests results

Table 8 shows the stability and diagnostic test.

The stability and diagnostic test results for oil consumption in different sectors have probability values for serial correlation and heteroscedasticity at 0.5216 and 0.7321. Similarly, the results for the gas consumption in different sectors have probability values for serial correlation and heteroscedasticity at 0.1671 and 0.8121 respectively.

## Structural stability test

Figures 5, 6, 7, and 8 illustrate the graph of CUSUM and CUSUM square at 5% level of significance and point to stable the long-run and short-run limitations. It approves the long-run and short-run limits stability.

## Granger causality test for short-run under vector error correction model

Table 9 reports the results of the Granger causality test for short-run under vector error correction model (VECM).

The presence of cointegration furnishes us an opportunity to measure the directional casual-based association between the study variables. Since autoregressive distributed lag (ARDL) bound testing model has been exerted and displayed that there is long-run cointegration existed in the variables, meanwhile, short-run granger causality under vector error correction model (VECM) may produce sufficient results to defining conclusion for strong future policy implications. Furthermore, evidences at hand in model for oil consumption confirmed the uni-directional linkages of oil consumption in agriculture and industrial sector with economic growth in Pakistan. Similarly, oil consumption in agriculture has one causation toward oil utilization for power in Pakistan. Additionally, the bi-directionally nexus was established amid oil consumption in the agriculture sector and oil utilization in the household sector.

Similarly, gas consumption investigation model demonstrated that gas consumption for household purposes and fertilizer production is significantly causative for gas commercialization. Moreover, gas utilization in household causatively in one way impacting gas consumption in fertilizers

**Table 9** Results of VECM Granger causality tests

For oil consumption in various sectors

Descriptive variables	Independent variables				
	$\Delta$ GDP	$\Delta$ OPOW	$\Delta$ OINDUS	$\Delta$ OHH	$\Delta$ OAGR
$\Delta$ GDP	–	5.5167 (0.1376)	19.7328 (0.002)***	1.0054 (0.7999)	11.6100 (0.0088)***
$\Delta$ OPOW	3.1155 (0.3741)	–	5.7647 (0.1236)	0.6493 (0.8851)	11.6602 (0.0086)***
$\Delta$ OINDUS	0.6056 (0.8951)	5.3531 (0.1477)	–	1.1221 (0.7717)	4.3715 (0.224)
$\Delta$ OHH	1.2565 (0.7395)	7.9738 (0.0466)**	3.1611 (0.3674)	–	6.7288 (0.0811)*
$\Delta$ OAGR	1.8672 (0.6004)	1.4012 (0.7052)	4.8634 (0.1821)	4.8933 (0.1798)	–

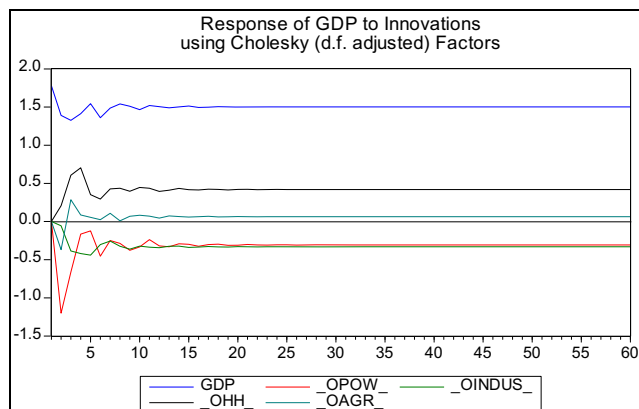
Descriptive variables	Independent variables				
	$\Delta$ GDP	$\Delta$ GCOM	$\Delta$ GINDUS	$\Delta$ GHH	$\Delta$ GFER
$\Delta$ GDP	–	1.0089 (0.7791)	3.1159 (0.3741)	3.4110 (0.3325)	3.8517 (0.2779)
$\Delta$ GCOM	3.0419 (0.3852)	–	5.2818 (0.1523)	27.811 (0.000)***	10.352 (0.0158)**
$\Delta$ GINDUS	0.6492 (0.8851)	2.2995 (0.5126)	–	20.156 (0.0002)***	3.0523 (0.3836)
$\Delta$ GHH	3.0530 (0.3835)	3.9796 (0.2637)	3.2608 (0.3531)	–	4.0365 (0.2575)
$\Delta$ GFER	3.5669 (0.3122)	9.9523 (0.0190)	3.6021 (0.3078)	8.4748 (0.0372)**	–

Note: \*Significance at 1% level, \*\*significance at 5% level, \*\*\*significance at 10% level

companies and industrial sectors. Thus, gas in household evidently indicated that government should initiate more gas-intensive projects that will mitigate the challenges of gas shortages and deliver it easily and cheaply to every household at their doorstep.

### Impulse response function

The impulse response function of oil energy consumption in the model results stipulate in Fig. 9, where at introductory, the reaction of gross domestic product for itself. In the first, three periods would have a decline but after that an upward trend may prevail till the next 60th period. Similarly, other variables will also have same trend till the end of 60th periods. Similarly, the gas consumption in the model demonstrates variations for gross domestic product, and other variables in

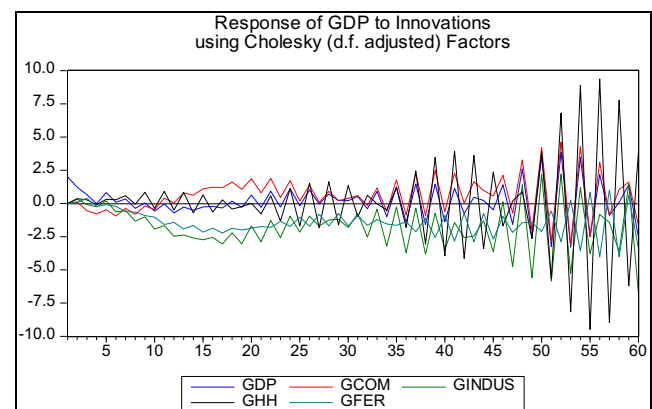


**Fig. 9** Impulse response function (IRF) for oil

the first 10 periods were not too much volatile, but after that, highly oscillated sample depiction will revert around its mean value (0) till 10+ to 10– in Fig. 10. Subsequently, after 55 periods, all model partner variables will reduce their volatility and start a normalizing trend.

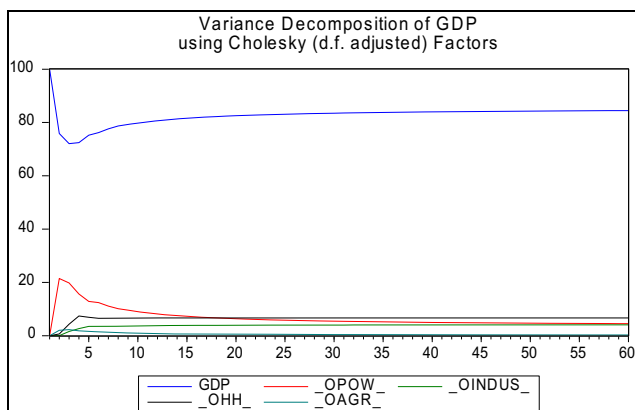
### Variance decomposition analysis

Figure 11 demonstrates that gross domestic product (GDP) shows declining trend in the first 5 periods and then flat at 80% end of 60th period, while the other variables oil consumption in power sector (OPOW), oil consumption in industry (OINDUS), oil consumption in households (OHH), and oil consumption in agriculture sector (OAGR) would have an upward tendency and then will prevail smooth till the 60th period. On the other hand, Fig. 12 identifies that gross



**Fig. 10** Impulse response function (IRF) for gas



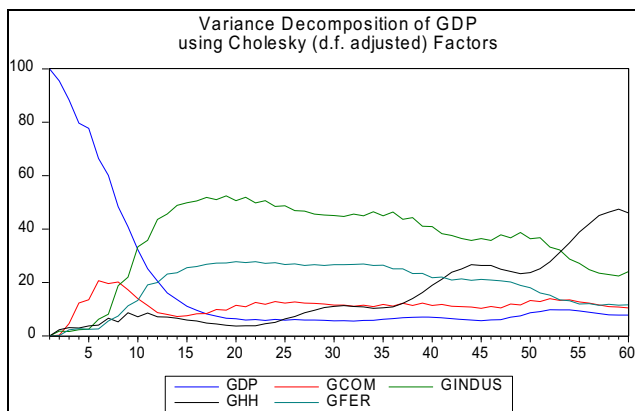


**Fig. 11** Variance decomposition analysis (VDA) for oil

domestic product (GDP) will have sharp declining trend from 100 to 80% in the first 10 periods. On the contrary, other variables would specify upward drive from 0 to 20% in the first 10 periods. Likewise, gas consumption in industry sector (GINDUS) reaches up to 58% and sustains 5 to 45% at the 60th period. Hence, we may treasure the implication that oil and gas consumption in Pakistan ought to be the top most pivotal landscapes for economic growth and its sustainability.

## Conclusion and policy implications

This country-specific study focuses on exploring the nexus between oil and natural gas consumption and its linkage with economic growth in Pakistan for the period of 1980–2016. The unit root test of Augmented Dickey–Fuller (ADF) was used to check the variables stationarity, while an autoregressive distributed lag (ARDL) bounds testing approach to cointegration was applied that accounts for the sectors of oil and natural gas consumption: households, industry, agriculture, power, fertilizers, and commercial. We established dynamic causality relationships under vector error correction model (VECM) context and autoregressive



**Fig. 12** Variance decomposition analysis (VDA) for gas

distributed lag (ARDL) bounds testing model among the variables and comment on their long-run and short-run relationships.

According to the results obtained, the oil consumptions by the agriculture and power sector have a positive and significant impact on the economic growth of Pakistan. Similarly, natural gas consumption by households, fertilizers, and industry sector also has a significant relationship with economic growth. At the same time, oil consumption by households and industry sector has a negative linkage with economic growth and natural gas consumption by the commercial sector has a negative effect on economic growth.

This study recommends that the government of Pakistan must improve energy policies and increase financial support to boost oil and natural gas energy production. It is important to explore the advantages of natural gas because the country is rich in natural gas, which is a viable and cheap alternative to the oil-generated energy. Similar to the exploitation of natural gas, other energy sources like hydroelectric, nuclear, and wind generators could be produced. Natural gas remains the cheapest source of energy to meet the energy demand of the country. Consequently, the key aim of sustainable energy is to increase the use of natural gas, to boost the efficacy of oil and natural gas, and to add to these initiatives a parallel investment in clean and renewable energy production. Although natural gas and crude oil will continue to be the most dominant energy sources for the next few years, they will dominate the production and future of renewable energy that is expected to secure them.

## Compliance with ethical standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

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