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By applying an ARDL bounds testing approach and causality test to investigate the electricity consumption and production with economic growth

Empirical evidence from Pakistan

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Abstract
Purpose – The purpose of this paper is to explore and investigate the electricity consumption and production and its linkage to economic growth in Pakistan.
Design/methodology/approach – The authors used an augmented Dickey–Fuller unit root test to check the stationarity of the variables, while an autoregressive distributed lag (ARDL) bounds testing approach and causality test were applied to investigate the variables long-term association with the economic growth.
Findings – The study results show that electricity consumption in the agriculture, commercial and industrial sector has significant association with economic growth, while electricity consumption in the household and street lights demonstrate a non-significant association with the economic growth. Furthermore, results also exposed that electricity production from coal, hydroelectric, natural gas, nuclear and oil sources have significant association with the economic growth of Pakistan.
Originality/value – This study made a contribution to the literature regarding electricity consumption and production with economic growth in Pakistan by using an ARDL bounds testing approach and causality test. This study provides a guideline to the government of Pakistan that possible steps are needed to improve the electricity production and supply to fulfill the country demand.

Keywords Pakistan, Economic growth, Electricity consumption, Electricity production, Industrial sector, Nuclear sources
Paper type Research paper

1. Introduction
The energy demand and consumption in the world has a sustained and stable growth in the past few decades, and developing economies and emerging markets are playing dominant role to boost economic growth and development. Urbanization and fast growing population has become the major component in the growth of world energy consumption. However, the consumption of large amount of non-renewable energy and growth in the energy consumption has fetched many serious impacts on the environment (Suganthi and Samuel, 2012;

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Panwar *et al.*, 2011; Ouedraogo, 2013; Liu and Li, 2011). The energy consumption pattern, technology, economic structure and human living standard are different from the developed economies, and distinctive natural resources of Pakistan deliver inexpensive sources of energy which includes coal, hydropower, solar energy and wind power (Farooq and Kumar, 2013). In developing countries, progress in the economic sector mainly reliant on electricity and production in the manufacturing industries decays due to shortages of electricity, which in turn undermine the economy. Economic growth is directly associated with the consumption of electricity consumption which is a key component to the labor and capital, and considered as a factor of production (Costantini and Martini, 2010; Wolde-Rufael, 2014).

In the modern global economy, electricity is seen as a multi-faceted development vehicle characterized by the consolidation and maintenance of human welfare, investment, productivity, exports and imports. These factors in turn have accelerated the trend of national economic growth and prosperity. Others believe that electricity consumption is conducive to sustainable economic growth and ensuring the continuity of national prosperity, regardless of the causality direction. Therefore, certain damages caused by the recent financial crisis, many countries are increasingly demanding significant development in the sustainable economic growth, which is gradually becoming a competitive challenge. In addition, it is necessary to attract and sustain large international investment flows and other international investment mechanisms are the foundation of each country (Rafindadi and Ozturk, 2016; Fukushige and Yamawaki, 2015; Karanfil and Li, 2015; Kim, 2015).

The association amid economic growth, energy consumption and CO_2 emission can be uttered through energy efficiency which has linkage to energy input and economic growth output. It is impacted by the development stage of economy and society, change in the energy consumption, adjustment of economic structure as well as the improvement and development in the living standard of people (Shiu and Lam, 2004; Ozturk, 2010; Zhang *et al.*, 2017; Zhang and Cheng, 2009; Rehman, Ozturk and Zhang, 2019). However, electricity production and its links with economic growth and environmental circumstances have become the key focus of attention around the world. Some countries use petroleum-related products in order to produce electricity which upsurge their need on energy (Mbarek *et al.*, 2015; Chen *et al.*, 2007; Payne, 2010a, b; Rehman, Rauf, Ahmad, Chandio and Deyuan, 2019).

Pakistan is a low-income country that has faced most serious energy crisis in the past few years, and its energy demand has increased with the growth of economy and population. Recycling of debt, fragile financial conditions of energy supply companies, dependence on natural gas and oil, declining natural gas production, low consumption of cheap hydropower and coal resources and energy shortages caused by unrestricted major restrictions on power generation (*Pakistan Energy Year Book*, 2009). Increasing oil prices have led to increase production costs and inflation, which has a negative impact on investment and purchasing power. Electricity supply is an essential element of industrial production, and different countries are facing power shortages which are unable to sustain economic growth. As compared with oil prices, economic growth in developing countries with industrial infrastructure has a high correlation with electricity consumption. Due to power shortages, the production process may also slow down (Das *et al.*, 2012; Damette and Seghir, 2013; Timilsina, 2015; Shahbaz and Ali, 2016).

Energy is an essential measure to promote economic growth of any country and development, and highly versatile system can stimulate energy performance of almost all sectors of the economy. The country is facing serious problems related to energy production and supply, and electricity demand is increasing with the rapid growth of population and electricity prices like other countries (Mohamed and Bodger, 2005; Rehman and Deyuan, 2018a, b; Rehman, Ozturk and Zhang, 2019; Rehman, Rauf, Ahmad, Chandio and Deyuan, 2019). The electricity production from fossil fuel demonstrates the independent power plants which are based on policy to upsurge the use of other thermal and heat power plants because of due to the high production efficiency of these plants (Burnard and Bhattacharya, 2011; Rafaschieri *et al.*, 1999; York, 2012). Energy has dominant contribution in the economy and considered a major source for various decades. The different sources of energy including coal, natural gas and electricity are used to run machines, vehicles, harvesting crops, fertilizers and irrigation, heating systems, factories and buildings. The usage of energy is involved in every step of process, production and people's daily life within the countries (Dogan, 2015). Energy and water are considered necessary resources for the human life. Recent approaches to energy systems and water have also facilitated the interconnection of these two resources. Energy is used to prepare, transfer and treat water, which in turn is used to enter, process and produce energy (Azofra *et al.*, 2015).

In the modern global economy, electricity is seen as a multi-faceted development vehicle which is characterized by the consolidation and maintenance of human welfare, investment and productivity. These aspects enhanced the trend of national economic growth and prosperity. Several studies has been conducted regarding energy consumption, renewable energy consumption, population growth, carbon dioxide emission, agricultural economic growth, electricity production, electricity prices, foreign direct investment, renewable power generation, industrial carbon dioxide emission growth, foreign direct investment inflows and economic growth (Mahadevan and Asafu-Adjaye, 2007; Belloumi, 2009; Payne, 2010a, b; Alshehry and Belloumi, 2015; Rehman *et al.*, 2018; Ahmad *et al.*, 2019; Chandio *et al.*, 2019; Rehman and Deyuan, 2018a, b; Kahia *et al.*, 2019; Lin and Nelson, 2019; Irfan *et al.*, 2019; Naz *et al.*, 2019). The main objective of this study was to investigate the electricity consumption and production and its linkage to economic growth in Pakistan. Time series data were used in this study and it was collected from the Economic Survey of Pakistan and the World Development Indicators (WDI). For variables stationarity, augmented Dickey–Fuller (ADF) unit root test was used, while an autoregressive distributed lag (ARDL) bounds testing approach with the analysis of long-run and short-run and causality test was used to check the dynamics association amid the variables. Besides the introduction section the remaining paper is organized as: the "Materials and Methods" section shows the study data sources and model specification. Section "Empirical Analysis" presents the persistence of ADF unit root test and specification of ARDL model to cointegration and "Results and Discussion" section demonstrates the descriptive statistics results of the variables for electricity consumption and production, covariance analysis, ADF unit root tests results, results of the cointegration test, long-run and short-run analysis results, pair-wise Granger causality tests results and structural stability test. "Conclusion and Policy Recommendations" section shows the conclusion of the study.

2. Materials and methods

2.1 Data sources

This study examined the electricity consumption and production in Pakistan and its association to economic growth over the period 1981–2017. Data were taken from the Economic Survey of Pakistan annual reports and the WDI. The variables used for the electricity consumption are: GDP growth (annual percent), electricity consumption in agriculture sector (in Gwh), electricity consumption in commercial sector (in Gwh), electricity consumption in households (in Gwh), electricity consumption in industrial sector (Gwh) and electricity consumption in street lights. Furthermore, the variables used for the electricity production are: electricity production from coal sources (in percentage of total), electricity production from hydropower sources (in percentage of total), electricity production from natural gas sources (in percentage of total), electricity production from nuclear sources (in percentage of total) and electricity production from oil sources (in percentage of total), respectively.

2.2 Model specification

To check the variables association we can specify model separately. The electricity consumption in different sectors and economic growth can be specified as:

$$GDP_t = \gamma_0 + \gamma_1 AS_t + \gamma_2 CS_t + \gamma_3 HH_t + \gamma_4 IS_t + \gamma_5 SL_t + \mu t. \quad (1)$$

Similarly, the electricity production from different sources and its linkage to economic growth can be specified as:

$$GDP_t = \Psi_0 + \Psi_1 EPC_t + \Psi_2 EPH_t + \Psi_3 EPNG_t + \Psi_4 EPN_t + \Psi_5 EPO_t + \mu t. \quad (2)$$

Equations (1) and (2) can also be written in the logarithm form as:

$$\ln GDP_t = \gamma_0 + \gamma_1 \ln AS_t + \gamma_2 \ln CS_t + \gamma_3 \ln HH_t + \gamma_4 \ln IS_t + \gamma_5 \ln SL_t + \mu t, \quad (3)$$

$$\ln GDP_t = \Psi_0 + \Psi_1 \ln EPC_t + \Psi_2 \ln EPH_t + \Psi_3 \ln EPNG_t + \Psi_4 \ln EPN_t + \Psi_5 \ln EPO_t + \mu t. \quad (4)$$

Equations (3) and (4) illustrate the variables log-linear form. $\ln GDP_t$ indicates the natural logarithm of gross domestic product, $\ln AS_t$ shows the natural logarithm of electricity consumption in agriculture sector, $\ln CS_t$ shows the natural logarithm of electricity consumption in commercial sector, $\ln HH_t$ shows the natural logarithm of electricity consumption in households, $\ln IS_t$ presents the natural logarithm of electricity consumption in industrial sector, and $\ln SL_t$ indicates the natural logarithm of electricity consumption in street lights, t demonstrates the time dimension, μt is the error term and the coefficients of the model γ_1–γ_5 represent the elasticity of the long-run.

Similarly, in the Equation (4), $\ln GDP_t$ indicates the natural logarithm of gross domestic product, $\ln EPC_t$ shows the natural logarithm of electricity production from coal sources, $\ln EPH_t$ shows the natural logarithm of electricity production from hydroelectric sources, $\ln EPNG_t$ shows the natural logarithm of electricity production from natural gas, $\ln EPN_t$ presents the natural logarithm of electricity production from nuclear sources and $\ln EPO_t$ indicates the natural logarithm of electricity production from oil sources, and the coefficients of the model Ψ_1–Ψ_5 represent the elasticity of the long-run.

3. Empirical analysis

3.1 Persistence of ADF unit root test

An ADF (Dickey and Fuller, 1979) unit root test was applied when ARDL model requisite no pretesting to check the stationarity of variables in the unit root test. It can be illustrated as:

$$\Delta Y_t = \alpha_0 + \beta_0 T + \beta_1 Y_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta Y_{t-1} + \mu_t. \quad (5)$$

In Equation (5), Y illustrates the variables being tested for unit root, T shows the linear trend, Δ shows the first difference, m is white noise residuals to gain, t is time and μt shows the error term.

3.2 Specification of ARDL model to cointegration

In order to check the long-run and short-run analysis amid study variable, this study employed an ARDL bounds testing approach which is first developed by Pesaran and Shin (1998) and Pesaran *et al.* (2001). The cointegration test approach is valid regardless for the order of integration and variable association in the order of zero or $I(1)$, apart from the $I(2)$. The demonstration of long-run and short-run followed the representation of unrestricted error correction model. The ARDL bounds testing model for energy consumption in different sectors can be specified as generally:

$$\begin{aligned}\Delta \mathrm{lnGDP}_t = {} & \psi_0 + \sum_{i=1}^{H} \psi_{1i} \Delta \mathrm{lnGDP}_{t-i} + \sum_{i=1}^{H} \psi_{2i} \Delta \mathrm{lnAS}_{t-i} + \sum_{i=1}^{H} \psi_{3i} \Delta \mathrm{lnCS}_{t-i} \\ & + \sum_{i=1}^{H} \psi_{4i} \Delta \mathrm{lnHH}_{t-i} + \sum_{i=1}^{H} \psi_{5i} \Delta \mathrm{lnIS}_{t-i} + \sum_{i=1}^{H} \psi_{6i} \Delta \mathrm{lnSL}_{t-i} + \beta_1 \mathrm{lnGDP}_{t-1} \\ & + \beta_2 \mathrm{lnAS}_{t-1} + \beta_3 \mathrm{lnCS}_{t-1} + \beta_4 \mathrm{lnHH}_{t-1} + \beta_5 \mathrm{lnIS}_{t-1} + \beta_6 \mathrm{lnSL}_{t-1} + \varepsilon_t. \end{aligned} \tag{6}$$

In Equation (6), Δ is operator to show difference, H illustrates the lags order and ε_t is the error term. The long-run association of electricity consumption in different sectors with economic growth can be specified as:

$$\begin{aligned}\Delta \mathrm{lnGDP}_t = {} & \vartheta_0 + \sum_{i=1}^{K} \vartheta_{1i} \Delta \mathrm{lnGDP}_{t-i} + \sum_{i=1}^{K} \vartheta_{2i} \Delta \mathrm{lnAS}_{t-i} + \sum_{i=1}^{K} \vartheta_{3i} \Delta \mathrm{lnCS}_{t-i} \\ & + \sum_{i=1}^{K} \vartheta_{4i} \Delta \mathrm{lnHH}_{t-i} + \sum_{i=1}^{K} \vartheta_{5i} \Delta \mathrm{lnIS}_{t-i} + \sum_{i=1}^{K} \vartheta_{6i} \Delta \mathrm{lnSL}_{t-i} + \varepsilon_t. \end{aligned} \tag{7}$$

Equation (7) shows the long-run analysis amid the study variable and K indicates the lags order. Similarly, the short-run analysis among the study variables can be demonstrated by the following error correction model (ECM), and can be specified as in the following equation:

$$\begin{aligned}\Delta \mathrm{lnGDP_t} = {} & \partial_0 + \sum_{i=1}^{F} \partial_{1\mathrm{i}} \Delta \mathrm{lnGDP}_{t-i} + \sum_{i=1}^{F} \partial_{2\mathrm{i}} \Delta \mathrm{lnAS}_{t-i} + \sum_{i=1}^{F} \partial_{3\mathrm{i}} \Delta \mathrm{lnCS}_{t-i} + \sum_{i=1}^{F} \partial_{4\mathrm{i}} \Delta \mathrm{lnHH}_{t-i} \\ & + \sum_{i=1}^{F} \partial_{5\mathrm{i}} \Delta \mathrm{lnIS}_{t-i} + \sum_{i=1}^{F} \partial_{6\mathrm{i}} \Delta \mathrm{lnSL}_{t-i} + \alpha \mathrm{ECM}_{t-1} + \varepsilon_t. \end{aligned} \tag{8}$$

Furthermore, in order to demonstrate the analysis for electricity production from different sources in Pakistan and its association with economic growth can be specified by using ARDL bounds testing model:

$$\begin{aligned}\Delta \mathrm{lnGDP_t} = {} & \phi_0 + \sum_{i=1}^{Q} \phi_{1\mathrm{i}} \Delta \mathrm{lnGDP}_{t-i} + \sum_{i=1}^{Q} \phi_{2\mathrm{i}} \Delta \mathrm{lnEPC}_{t-i} + \sum_{i=1}^{Q} \phi_{3\mathrm{i}} \Delta \mathrm{lnEPH}_{t-i} \\ & + \sum_{i=1}^{Q} \phi_{4\mathrm{i}} \Delta \mathrm{lnEPNG}_{t-i} + \sum_{i=1}^{Q} \phi_{5\mathrm{i}} \Delta \mathrm{lnEPN}_{t-i} + \sum_{i=1}^{Q} \phi_{6\mathrm{i}} \Delta \mathrm{lnEPO}_{t-i} \\ & + \lambda_1 \mathrm{lnGDP}_{t-1} + \lambda_2 \mathrm{lnEPC}_{t-1} + \lambda_3 \mathrm{lnEPH}_{t-1} + \lambda_4 \mathrm{lnEPNG}_{t-1} \\ & + \lambda_5 \mathrm{lnEPN}_{t-1} + \lambda_6 \mathrm{lnEPO}_{t-1} + \varepsilon_t, \end{aligned} \tag{9}$$

where Q illustrates the lags order in the equation, and the analysis of long-run amid study variables can be specified as:

$$\Delta \mathrm{lnGDP_t} = \zeta_0 + \sum_{i=1}^{Q} \zeta_{1i} \Delta \mathrm{lnGDP}_{t-i} + \sum_{i=1}^{Q} \zeta_{2i} \Delta \mathrm{lnEPC}_{t-i} + \sum_{i=1}^{Q} \zeta_{3i} \Delta \mathrm{lnEPH}_{t-i} + \sum_{i=1}^{Q} \zeta_{4i} \Delta \mathrm{lnEPNG}_{t-i} + \sum_{i=1}^{Q} \zeta_{5i} \Delta \mathrm{lnEPN}_{t-i} + \sum_{i=1}^{Q} \zeta_{6i} \Delta \mathrm{lnEPO}_{t-i} + \varepsilon_t. \quad (10)$$

Equation (10) demonstrates the long-run analysis of electricity production from different sources in Pakistan. Similarly, the short-run analysis among study variables can be specified as in the following equation:

$$\Delta \mathrm{lnGDP_t} = \varphi_0 + \sum_{i=1}^{W} \varphi_{1i} \Delta \mathrm{lnGDP}_{t-i} + \sum_{i=1}^{W} \varphi_{2i} \Delta \mathrm{lnEPC}_{t-i} + \sum_{i=1}^{W} \varphi_{3i} \Delta \mathrm{lnEPH}_{t-i} + \sum_{i=1}^{W} \varphi_{4i} \Delta \mathrm{lnEPNG}_{t-i} + \sum_{i=1}^{W} \varphi_{5i} \Delta \mathrm{lnEPN}_{t-i} + \sum_{i=1}^{W} \varphi_{6i} \Delta \mathrm{lnEPO}_{t-i} + \alpha ECM_{t-1} + \varepsilon_t. \quad (11)$$

Equation (11) shows the short-run analysis for the electricity production from different sources and economic growth.

4. Results and discussion

4.1 Descriptive statistics results of the variables for electricity consumption and production

The descriptive statistics results are reported in Tables I and II.

4.2 Covariance analysis

The covariance analysis results for the electricity consumption and electricity production are interpreted in Tables III and IV, which illustrates that all variables have correlation.

Tables III and IV represent the correlation linkage between economic growth, electricity consumption and electricity production.

	LNGDP	LNAS	LNCS	LNHH	LNIS	LNSL
Mean	6.401058	8.636283	7.971694	9.704449	9.486410	5.594270
Median	6.214328	8.702178	7.872074	9.872719	9.476007	5.697093
Maximum	7.344624	9.178747	8.969033	10.79339	10.12803	6.182085
Minimum	5.806568	7.666222	6.860664	7.899524	8.417594	4.615121
SD	0.514084	0.426473	0.599458	0.810496	0.485706	0.496133
Skewness	0.546915	−0.839105	−0.032018	−0.665357	−0.575240	−0.637329
Kurtosis	1.796567	2.634296	1.926822	2.349391	2.401585	2.207672
Jarque–Bera	4.077268	4.548113	1.781876	3.382555	2.592631	3.472660
Probability	0.130206	0.102894	0.410271	0.184284	0.273538	0.176166
Sum	236.8391	319.5425	294.9527	359.0646	350.9972	206.9880
Sum Sq. Dev.	9.514159	6.547637	12.93659	23.64852	8.492779	8.861317
Observations	37	37	37	37	37	37

Table I. Descriptive statistics results for electricity consumption

Table II.
Descriptive statistics results for electricity production

	LNGDP	LNEPC	LNEPH	LNEPNG	LNEPN	LNEPO
Mean	1.407870	−1.804867	3.621071	3.446015	0.497724	3.212959
Median	1.542167	−1.950741	3.535466	3.420301	0.559013	3.427757
Maximum	2.069488	−0.258107	4.071392	3.927263	1.711428	3.732231
Minimum	0.014293	−4.076859	3.124723	3.220114	−2.445270	1.379297
SD	0.509150	0.812412	0.265860	0.167044	0.880211	0.526401
Skewness	−0.759348	0.018112	0.237630	1.167282	−0.926139	−1.422596
Kurtosis	3.045214	3.448081	1.829222	4.308548	4.427740	5.120692
Jarque–Bera	3.558911	0.311554	2.461413	11.04217	8.431960	19.41337
Probability	0.168730	0.855750	0.292086	0.004001	0.014758	0.000061
Sum	52.09120	−66.78009	133.9796	127.5026	18.41580	118.8795
Sum Sq. Dev.	9.332422	23.76046	2.544537	1.004529	27.89178	9.975536
Observations	37	37	37	37	37	37

Table III.
Covariance analysis results for electricity consumption

Correlation *t*-Statistic Probability	LNGDP	LNAS	LNCS	LNHH	LNIS	LNSL
LNGDPPC	1.000000					
	–					
	–					
LNAS	0.818676	1.000000				
	8.434139	–				
	0.0000	–				
LNCS	0.957780	0.913724	1.000000			
	19.70863	13.30342	–			
	0.0000	0.0000	–			
LNHH	0.875446	0.947254	0.957702	1.000000		
	10.71597	17.48624	19.68939	–		
	0.0000	0.0000	0.0000	–		
LNIS	0.893740	0.951579	0.969790	0.986351	1.000000	
	11.78695	18.31346	23.51946	35.44009	–	
	0.0000	0.0000	0.0000	0.0000	–	
LNSL	0.820763	0.962959	0.874565	0.896470	0.906358	1.000000
	8.499862	21.12740	10.67003	11.96915	12.69103	–
	0.0000	0.0000	0.0000	0.0000	0.0000	–

4.3 ADF unit root tests results

The results of ADF unit root test with trend and intercept for electricity consumption and electricity production are reported in Tables V and VI at the level, and at first differences.

In the order of $I(2)$, it shows that none of the variable integrated, so, therefore, ARDL model was applied.

4.4 Cointegration test

The selected level of significance demonstrates when W or F-statistic used and then a cointegration test was applied. Tables VII and VIII reported the results of cointegration test.

Tables VII and VIII show the cointegration summary and variables existence and their association at the significance level 1, 5 and 10 percent. Tables IX and X reported the Johansen cointegration test for both electricity consumption and electricity production.

Correlation *t*-Statistic Probability	LNGDP	LNEPC	LNEPH	LNEPNG	LNEPN	LNEPO
LNGDP	1.000000 – –					
LNEPC	−0.228739 −1.390091 0.1733	1.000000 – –				
LNEPH	0.467554 3.129186 0.0035	−0.302645 −1.878570 0.0687	1.000000 – –			
LNEPNG	0.359922 2.282277 0.0287	−0.082607 −0.490386 0.6269	−0.075302 −0.446759 0.6578	1.000000 – –		
LNEPN	−0.114315 −0.680761 0.5005	−0.101824 −0.605548 0.5487	−0.493500 −3.356827 0.0019	0.064996 0.385337 0.7023	1.000000 – –	
LNEPO	−0.634855 −4.861121 0.0000	0.278742 1.717113 0.0948	−0.731103 −6.339553 0.0000	−0.426285 −2.787934 0.0085	0.300672 1.865100 0.0706	1.000000 – –

Table IV. Covariance analysis results for electricity production

Variables	Level	1st Diff.	Order of integration
LNGDP	−1.921965 (0.6225)	−4.061218 (0.0190)***	*I*(1)
LNAS	−2.455515 (0.3467)	−3.986948 (0.0185)***	*I*(1)
LNCS	−3.079929 (0.1263)	−5.911137 (0.0001)***	*I*(1)
LNHH	−3.515878 (0.0527)**	−4.155436 (0.0124)***	*I*(0)
LNIS	−2.183211 (0.4837)	−3.487424 (0.0564)**	*I*(1)
LNSL	−2.898163 (0.1756)	−5.208175 (0.0008)***	*I*(1)

Notes: **,***Significant at 5 and 1 percent levels, respectively

Table V. ADF unit root test results for electricity consumption

Variables	Level	1st Diff.	Order of integration
LNGDP	−3.084151 (0.1270)	−3.713650 (0.0369)**	*I*(1)
LNEPC	−3.308608 (0.0810)*	−11.56685 (0.0000)***	*I*(0)
LNEPH	−0.924310 (0.9417)	−3.692650 (0.0385)**	*I*(1)
LNEPNG	−3.334771 (0.0794)*	−4.580896 (0.0043)***	*I*(0)
LNEPN	−3.361638 (0.0727)*	−0.768686 (0.9560)	*I*(0)
LNEPO	−2.559792 (0.2997)	−5.154347 (0.0010)***	*I*(1)

Notes: *,**,***Significant at 10, 5 and 1 percent levels, respectively

Table VI. ADF unit root test results for electricity production

4.5 Long-run and short-run analysis results

The results of the long-run analysis are illustrated in Table XI.

In the model focusing on the variables elasticity, Panel A results of long-run analysis show that electricity consumption in agriculture sector, commercial sector and industrial sector has significant association with economic growth with coefficients 0.662971, 1.226464 and 0.431695 with *p*-values 0.5057, 0.0004 and 0.5567, respectively. Similarly, electricity

Table VII.
ARDL Bounds test results for electricity consumption

Test statistic	Value	K
F-statistic	4.191583**	5
Critical value bounds		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68
Diagnostic tests		
R^2	0.486894	
Adjusted R^2	0.334863	
F-statistic	3.202592	
Prob (F-statistic)	0.010912	
Serial correlation	1.743344 (0.1982)	
ARCH	2.391370 (0.1082)	
Ramsey	1.814403 (0.1837)	

Note: **Significant at 5 percent

Table VIII.
ARDL Bounds test results for electricity production

Test statistic	Value	K
F-statistic	6.044159***	5
Critical value bounds		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68
Diagnostic tests		
R^2	0.584453	
Adjusted R^2	0.461328	
F-statistic	4.746821	
Prob (F-statistic)	0.001018	
Serial correlation	0.259119 (0.8541)	
ARCH	0.352018 (0.7880)	
Ramsey	0.152029 (0.8598)	

Note: ***Significant at 1 percent

consumption in the households and street lights has non-significant association with economic growth with coefficients −0.340251 and −0.454852 with *p*-values 0.3887 and 0.4634. Furthermore, Panel B results of long-run analysis for electricity production from different sources demonstrate that electricity production from coal sources in Pakistan had a coefficient of 0.078394, which is significant with *p*-value 0.4148. Similarly, the coefficients of electricity production from hydroelectric, natural gas, nuclear and oil sources also has significant association with economic growth having coefficients 1.782075, 1.694270, 0.210999 and 0.149428 with *p*-values 0.0662, 0.0456, 0.0721 and 0.7688, respectively. The electricity production from different sources depends on cost and several other factors, but the main sources include natural gas, oil, coal nuclear energy and hydropower. Oil prices and the combined usage of electricity consumption are expanding the production functions

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical value	Prob.**
Trace test				
None*	0.791904	167.2653	95.75366	0.0000
At Most 1*	0.691993	112.3238	69.81889	0.0000
At Most 2*	0.603552	71.10669	47.85613	0.0001
At Most 3*	0.441161	38.72431	29.79707	0.0036
At Most 4*	0.397652	18.35803	15.49471	0.0180
At Most 5	0.017442	0.615847	3.841466	0.4326
Maximum eigenvalue test				
None*	0.791904	54.94141	40.07757	0.0005
At Most 1*	0.691993	41.21715	33.87687	0.0056
At Most 2*	0.603552	32.38238	27.58434	0.0112
At Most 3	0.441161	20.36628	21.13162	0.0637
At Most 4*	0.397652	17.74218	14.26460	0.0135
At Most 5	0.017442	0.615847	3.841466	0.4326

Notes: Max-eigenvalue test indicates three cointegrating eqn(s) at the 0.05 level. *Denotes rejection of the hypothesis at the 0.05 level; ***p*-values

Table IX. Cointegration test results for electricity consumption

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical value	Prob.**
Trace test				
None*	0.813990	154.9916	117.7082	0.0000
At Most 1*	0.692417	97.80518	88.80380	0.0096
At Most 2	0.539893	57.71887	63.87610	0.1478
At Most 3	0.354325	31.32482	42.91525	0.4256
At Most 4	0.262286	16.45124	25.87211	0.4569
At Most 5	0.164446	6.108459	12.51798	0.4466
Maximum eigenvalue test				
None*	0.813990	57.18644	44.49720	0.0013
At Most 1*	0.692417	40.08631	38.33101	0.0311
At Most 2	0.539893	26.39405	32.11832	0.2128
At Most 3	0.354325	14.87359	25.82321	0.6458
At Most 4	0.262286	10.34278	19.38704	0.5822
At Most 5	0.164446	6.108459	12.51798	0.4466

Notes: Max-eigenvalue test indicates two cointegrating eqn(s) at the 0.05 level. *Denotes rejection of the hypothesis at the 0.05 level; ***p*-values

Table X. Cointegration test results for electricity production

will also provide new guidelines to the policy makers to design comprehensive growth policies while considering the role regarding electricity consumption and oil prices in the country. In the production function the unfamiliarity of associated variables in production function may be also the one cause for uncertainty in the literature of previous research. The increased reliance on expensive furnace oil in thermoelectric production, coupled with fluctuations in international oil prices, has a negative impact on the cost structure of electricity production and may further jeopardize energy shortages in Pakistan (Kessides, 2013; Komal and Abbas, 2015; Jamil and Ahmad, 2010; Hussain *et al.*, 2016). For example, the financial sector growth has improved the supply of funds for investment projects, thereby promoting industrial growth and expanding the production activities.

Table XI.
Long-run and short-run analysis results

Panel A: long-run and short-run results for electricity consumption					Panel B: long-run and short-run results for electricity production				
Variable	Coefficient	SE	*t*-statistic	Prob.*	Variable	Coefficient	SE	*t*-statistic	Prob.*
Long-run analysis					*Long-run analysis*				
LNAS	0.662971	0.982824	0.674557	0.5057	LNEPC	0.078394	0.094659	0.828167	0.4148
LNCS	1.226464***	0.305022	4.020907	0.0004	LNEPH	1.782075*	0.930712	1.914744	0.0662
LNHH	−0.340251	0.388402	−0.876028	0.3887	LNEPNG	1.694270**	0.808507	2.095554	0.0456
LNIS	0.431695	0.725355	0.595150	0.5567	LNEPN	0.210999*	0.112717	1.871931	0.0721
LNSL	−0.454852	0.611547	−0.743772	0.4634	LNEPO	0.149428	0.503189	0.296962	0.7688
C	−7.483486	6.191359	−1.208698	0.2373	C	−11.336124	7.441546	−1.523356	0.1393
Short-run analysis					*Short-run analysis*				
DLNGDP(−1)	0.793654***	0.076650	10.35431	0.0000	DLNGDP(−1)	−0.046827	0.171527	−0.272998	0.7869
DLNAS	−0.054357	0.160515	−0.338644	0.7375	DLNEPC	0.082065	0.098216	0.835554	0.4107
DLNAS(−1)	0.191159	0.125086	1.528218	0.1381	DLNEPH	0.166621	0.567549	0.293580	0.7713
DLNCS	0.253075**	0.117108	2.161046	0.0397	DLNEPH(−1)	1.698903**	0.775540	2.190607	0.0373
DLNHH	0.706369**	0.316275	2.233404	0.0340	DLNEPNG	0.779386	0.977574	0.797266	0.4323
DLNHH(−1)	−0.776579***	0.288827	−2.688732	0.0121	DLNEPNG(−1)	0.994220	0.753756	1.319021	0.1982
DLNIS	0.089078	0.140975	0.631876	0.5328	DLNEPN	0.220880*	0.116214	1.900637	0.0681
DLNSL	−0.093857	0.105486	−0.889752	0.3815	DLNEPO	0.156425	0.526344	0.297192	0.7686
CointEq(−1)	−0.206346***	0.076650	−2.692060	0.0120	CointEq(−1)	−1.046827***	0.171527	−6.102973	0.0000
Diagnostic tests					*Diagnostic tests*				
R^2	0.992099				R^2	0.530177			
Adjusted R^2	0.989757				Adjusted R^2	0.390970			
F-statistic	423.7638***				*F*-statistic	3.808557***			
Prob (*F*-statistic)	0.000000				Prob (*F*-statistic)	0.004136			
Normality test	2.318838 (0.3136)				Normality test	2.094162 (0.1078)			
Serial correlation	1.977108 (0.1595)				Serial correlation	0.189775 (0.8283)			
ARCH	1.772385 (0.1922)				ARCH	0.410372 (0.6670)			
Ramsey	0.868472 (0.3931)				Ramsey	0.554905 (0.5837)			
CUSUM	Stable				CUSUM	Stable			
CUSUMSQ	Stable				CUSUMSQ	Stable			

Notes: *,**,***Significant at 1, 5 and 10 percent levels, respectively

It promotes economic growth and upsurges the demand for new structure and more reliance on energy, which has a significant influence on energy consumption (Shahbaz and Lean, 2012; Kakar *et al.*, 2011). In the modern global economy, electricity is seen as a multi-faceted development vehicle characterized by the consolidation and maintenance of human welfare, investment, productivity, exports and imports. These factors in turn have accelerated the trend of national economic growth and prosperity. Others believe that electricity consumption is conducive to sustain economic growth and to ensure the continuity of national prosperity, regardless of the causality direction. Therefore, given the damage caused by the recent financial crisis, countries are increasingly demanding significant growth in sustainable economic growth, which is increasingly becoming a competitive challenge. In addition, it is necessary to attract and sustain large international investment flows and other international investment mechanisms which is the corner stone of each country (Rafindadi and Ozturk, 2016; Fukushige and Yamawaki, 2015; Karanfil and Li, 2015; Kim, 2015).

The short-run analysis results amid variables in the Panels A and B display that by employing an ECM which indicates the dynamics of the variables in the short-run analysis. Short-run analysis results for electricity consumption in different sectors revealed that R^2 value is about 99 percent, which shows the variation in the economic growth and explains 99 percent variation of independent variables. The joint significance of the *F*-statistic confirmed the level of significance of variables at 1 percent. The values of normality test, serial correlation, ARCH and Ramsey are 2.318838, 1.977108, 1.772385 and 0.868472, respectively. Similarly, the short-run analysis results for electricity production from different sources revealed that R^2 value is about 53 percent, which shows the variation in economic growth and explains 53 percent variation of independent variables, and the values of normality test, serial correlation, ARCH and Ramsey are 2.094162, 0.189775, 0.410372 and 0.554905, respectively.

4.6 Pair-wise Granger causality tests results

The pair-wise Granger causality test was used to check the causality among the study variables, and it has three categories including bidirectional, unidirectional and no causality. The results of pair-wise Granger causality for electricity consumption in different sectors and electricity production from different sources are reported in Tables XII and XIII. Results demonstrated the causality amid study variables at 10, 5 and 1 percent.

4.7 Structural stability test

The structural stability tests with cumulative sum (CUSUM) and cumulative sum of square (CUSUM) point were executed to stabilize the limits of long-run and short-run analysis for electricity consumption and electricity production. The graphs of CUSUM and CUSUM

Null hypothesis	*F*-statistic	Prob.
LNAS does not Granger cause LNGDP	2.04375	0.1622
LNGDP does not Granger cause LNAS	0.61707	0.4377
LNCS does not Granger cause LNGDP	3.44282	0.0725*
LNGDP does not Granger cause LNCS	1.52953	0.2249
LNHH does not Granger cause LNGDP	2.87805	0.0992*
LNGDP does not Granger cause LNHH	1.07738	0.3068
LNSL does not Granger cause LNGDP	4.61651	0.0391**
LNGDP does not Granger cause LNSL	0.00300	0.9566

Notes: *,**Significant at 10 and 5 percent levels, respectively

Table XII. Pair-wise Granger causality tests results for electricity consumption

Table XIII.
Pair-wise Granger causality tests results for electricity production

Null hypothesis	F-statistic	Prob.
LNEPC does not Granger cause LNGDP	1.22579	0.2762
LNGDP does not Granger cause LNEPC	2.00360	0.1663
LNEPH does not Granger cause LNGDP	5.52628	0.0249**
LNGDP does not Granger cause LNEPH	0.10787	0.7447
LNEPNG does not Granger cause LNGDP	2.96032	0.0947*
LNGDP does not Granger cause LNEPNG	1.10632	0.3005
LNEPN does not Granger cause LNGDP	0.15201	0.6991
LNGDP does not Granger cause LNEPN	1.23469	0.2745
LNEPO does not Granger cause LNGDP	13.2906	0.0009***
LNEPC does not Granger cause LNEPH	0.21539	0.6456

Notes: *,**,***Significant at 10, 5 and 1 percent levels, respectively

square tests are stated in Figures 1–4, and show that all values lay inside the critical boundaries at a 5 percent significance level. The stability test confirms the long-run and short-run structure.

5. Conclusion and recommendations

The main objective of this study was to investigate and explore the energy consumption and energy production with economic growth in Pakistan. Time series data were used in this study and it was collected from the Economic Survey of Pakistan and the WDI. We used an ADF unit root test to check the stationarity of the variables, while an ARDL bounds testing approach with the analysis of long-run and short-run was used to examine the causality association among the study variables. The results revealed that electricity consumption in agriculture sector, industrial sector and commercial sector has significant association with economic growth, while electricity consumption in the households and street lights has a non-significant association with the economic growth of Pakistan. Furthermore, the results

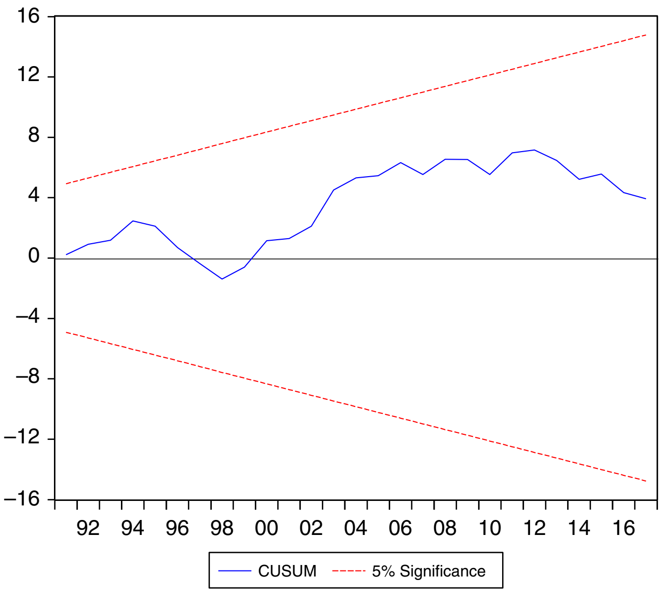

Figure 1.
Plot of CUSUM test (electricity consumption)

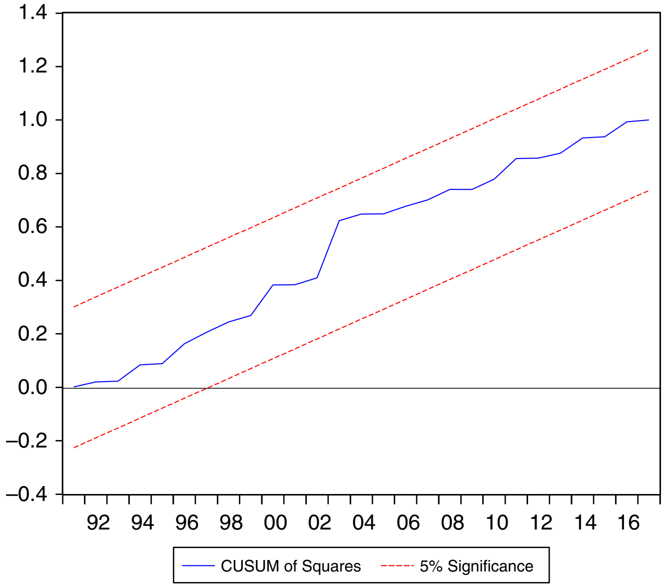

Figure 2.
Plot of CUSUM of squares test (electricity consumption)

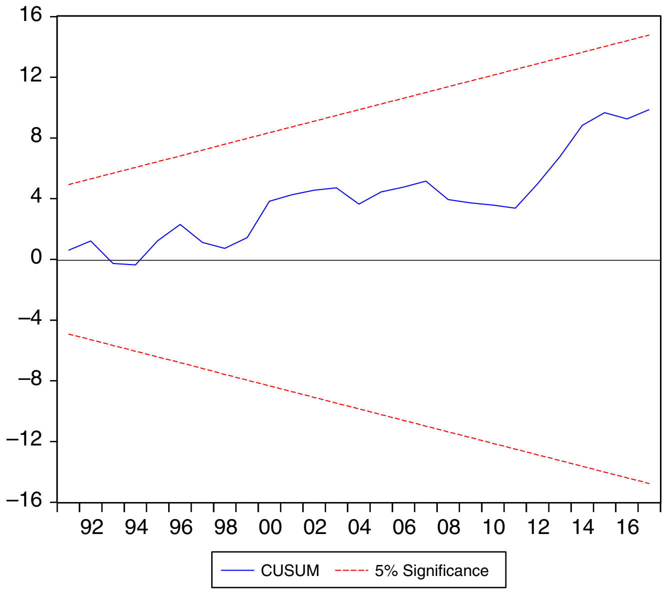

Figure 3.
Plot of CUSUM test (electricity production)

of electricity production demonstrated that electricity production from coal, hydroelectric, natural gas, nuclear and oils sources has significant association with the economic growth of Pakistan. According to these findings, this study suggests and provides guidelines to the government of Pakistan to pay more attention to produce cheap electricity from alternative sources to fulfill the country demands.

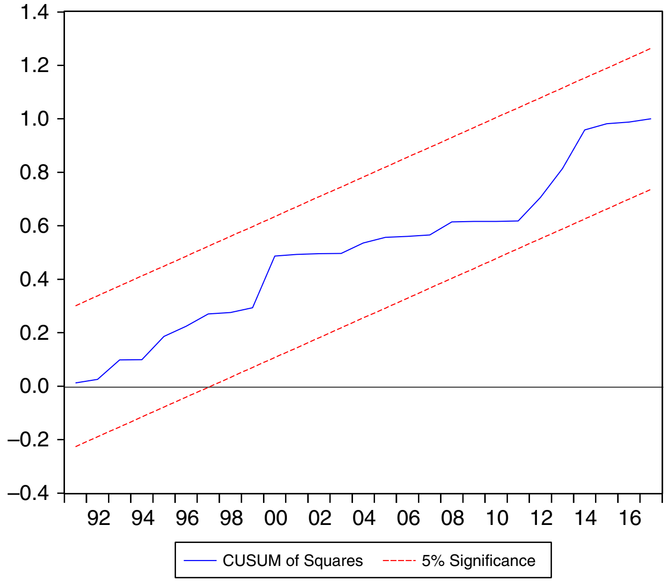

Figure 4.
Plot of CUSUM of squares test (electricity production)

Pakistan can benefit from the solar energy by installing solar systems in the country to produce cheap electricity. With the passage of time, the population of Pakistan is increasing and more electricity is required to accomplish the country needs. Wind energy can also be another alternative source to produce cheap electricity. As oil and natural gas are the key sources of energy to produce electricity, Pakistan can get further benefit from these sources by introducing new policies and financing schemes. It is also necessary for the government to introduce short, mid and long-term policies regarding energy production to boost the energy sector. Possible initiatives are required to produce energy from solar system to supply cheap electricity to the population of the country. Hence, this study suggests and recommends that the government provide financing schemes to help and develop the electricity sector and its production from a variety of sources.

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