Environment, Development and Sustainability (2020) 22:6149–6170
https://doi.org/10.1007/s10668-019-00468-4

Analysis of coal-related energy consumption in Pakistan: an alternative energy resource to fuel economic development

Muhammad Yousaf Raza[1] · **Muhammad Tauqir Sultan Shah**[2]

Received: 12 May 2019 / Accepted: 9 September 2019 / Published online: 20 September 2019

Abstract

During the last 4 decades, the world has changed its focus from imported energy resources to cheap resources either renewable or non-renewable for economic and social development. Currently, coal is the cheapest source of energy in Pakistan that can be used to fulfil the energy demands. This study inspects the causal association among domestic factors such as gross domestic product, coal consumption, rural–urban unemployment, rural–urban population, fiscal deficit and services value added from 1981 to 2017. This paper applies modern techniques to inspect the association between coal consumption and economic development of Pakistan. For this, Ng–Perron unit root test, autoregressive distributed lag models and vector error correction models are employed to examine the causalities between the factors. The research finds a long-run and short-run bidirectional association between economic improvement and coal use. In the short run, the results found a bidirectional causality among gross domestic product (GDP), coal consumption, unemployment, population and overall fiscal deficit. In the long run, GDP and coal use have a bidirectional association and the same is true with the other factors. During the period, cumulative sum (CUSUM) and CUSUM square have proved that structure is good. Moreover, we support the coal consumption in producing cheap energy that clues to financial development and unemployment reduction in Pakistan. The policy suggestions for the consequences are provided below.

Keywords Economic growth · Coal consumption · Urban–rural population and unemployment · Ng–Perron test

✉ Muhammad Yousaf Raza
yousaf.raza@ymail.com

Muhammad Tauqir Sultan Shah
tauqirsshah@gmail.com

[1] School of Management, Collaborative Innovation Center for Energy Economics and Energy Policy, China Institute for Studies in Energy Policy, China Centre for Energy Economics Research (CCEER), Xiamen University, Xiamen 361005, Fujian, China

[2] School of Management, Federal Urdu University of Arts Science and Technology, Islamabad 44000, Pakistan

Abbreviations

IAT	Innovative accounting technique
VECM	Vector error correction model
ARDL	Autoregressive distributed lags model
J&JT	Johansen and Juselius technique
HVGC	Hsiao's version of Granger causality
LBNL	Lawrence Berkeley National Laboratory
EC	Energy consumption
EG	Economic growth
CC	Coal consumption
RE	Renewable energy
L&C	Labour and capital
FC	Fuel consumption
GCA	Granger causality analysis
[ ]	Probabilities
LCB	Lower critical bound
UCB	Upper critical bound
Mt	Million tons
Mtoe	Million tons of oil equivalents
GDP	Gross domestic product
CO_2	Carbon dioxide
DF	Dickey and Fuller
PP	Phillips and Perron
GC	Granger causality
DV	Dependent variable
KPK	Khyber Pakhtunkhwa
VAR	Vector autoregressive
GLS	Generalized least square
EE	Energy efficiency
FD	Financial development
EI	Energy intensity
EAE	Economic activity effect
LM	Lagrange multiplier
$\longrightarrow$	Unidirectional causality
$\longleftrightarrow$	Bidirectional causalities
#	No causality
CUSUM	Cumulative sum
CUSUM square	Cumulative sum of square
CWS	Coal water slurry
CPEC	China Pakistan Economic Corridor
Btu/LB	British thermal unit/pound
LN	Natural log
ECT	Error correction term
LMDI	Logarithmic mean Divisia index
LCU	Local currency unit
EKC	Environmental Kuznets curve
SVA	Services value added
y_t^d	De-trending value
$\hat{\lambda}^2$	Consistent estimate of λ^2

PES	Pakistan Economic Survey (various issues)
SRWE	Statistical review of world energy
AJK	Azad Jammu and Kashmir
ADF	Augmented Dickey–Fuller
SD	Standard deviation

1 Introduction

Various, reasonable, secure and environmental adequate provisions of power are important to the maintainable growth of global cultures (Statistical Review of World Energy 2018). Approximately two billion people do not have access to a secure and safe supply of electricity which shows that worldwide electricity supply would double in the next 60 years. It is due to the limited amount of fossil fuel on the earth (Lewandowska-Bernat and Desideri 2018). It is, therefore, many countries are investing in the existing, renewable energy and energy-saving technologies. The economic progress cannot be obtained for long run without satisfying and affordable energy resources such as fossil fuels. Among the fossil fuels, coal has the highest significant contributions. In the nineteenth century, coal reserved countries are considered as developed countries in the world. Therefore, this study discloses that economic growth may be enhanced by using technical and efficient energy resources (Satti et al. 2014). This develops in achieving the expectation for everyday comforts and production of a nation. Due to the high consumption of petroleum products, import of oil, liquefied petroleum gas (LPG) and liquefied natural gas (LNG) will be costly sources of energy in Pakistan (Pakistan Energy Yearbook 2018).

Unlike other energies, coal is relatively cheap and abundant in Pakistan. Using coal is the most important cause of world climate change because energy plants discharge CO_2 emissions (Wolde-Rufael 2010). According to Pakistan Economic Survey (2018), domestic coal production is 1,022,821 tons of oil equivalents (Toe) in 2017–2018. The complete demonstrated Pakistan's coal assets are 186 billion tons that can be used for cheap energy production. Hence, the Government of Pakistan (GOP) has investigated coal resources in Baluchistan, Punjab, Khyber Pakhtunkhwa (KPK) and Azad Jammu and Kashmir (AJK) ensuring heating regard of 9000–15,000 Btu/LB which shows that coal–water slurry (CWS) is fruitful and energy production cost is lower than other assets (Vision 2035 2014). From a few decades, due to the heavy shortage of energy, many business projects did not improve their power creation. To fulfil the present and future demands, authorities are planning to install new capacities. For this, Pakistan has contracted value of $46 billion China Pakistan Economic Corridor (CPEC) plan including energy projects ($33.8b). In this underlying phase, the energy plans involve coal control ventures (worth of 7560 MW) and renewable power technology (capacity of 2790 MW). The renewable energy and coal schemes values are $8.8 billion and $6.4 billion, respectively (Pakistan Economic Survey 2017). The association between coal ingesting and financial development is important in the situation of causality. Due to the excess production of coal in Pakistan, consumption may influence the environment and economic growth. Apergis and Payne (2010a, b) posit that if the similar causality flows than coal consumption release greenhouse gas (GHG) that may be destructive for financial development. Currently, greater than 50 per cent (%) business units of small and large industries are inefficient throughout the summer period due to an energy crisis. In 2017, the consumption of non-renewable energy sources, such as petroleum products, nuclear energy, coal and natural gas of Pakistan, increased by 3.5%, 6.7%, 26.2% and 39.5%, respectively. Renewable energy consumption has increased by 33%, while hydropower has decreased by −9.8% during 2017 (Statistical Review of World Energy 2018). Observing in the past 11 years, the new generation capacity has increased by around 40%, but yet it is less than energy demand in Pakistan. Presently, the maximum production of coal is consumed in the power plants (2.6%), coke use (1.75%), cement industry (54.4%) and brick kilns (41.5%). The high share of coal shows the industry switched from petroleum products to coal. However, the coal power takes much time in development because of infrastructure, financing and mining technologies. The per capita consumption of energy has increased due to improper management, uncontrolled population and growth in business activities such as industries, firms and agriculture. These factors such as per capita income, services sectors, housing schemes and the expensive supply of electricity in rural areas have given a rising trend for energy in Pakistan. The major purpose of the existing research is to pay attention to authorities towards available alternative energy sources than expensive resources such as oil.

Even till the 1960s, between the basic means of power, coal was the only major power source. China is now the biggest coal user and producer inside the globe, accounting for 46.4 per cent of the worldwide coal production and 50.7 per cent of the worldwide coal ingestion in 2017 (Statistical Review of World Energy 2018). According to Wenbo and Yan (2018), coal represents 85% of the total energy consumption in China. Due to different alternatives energy sources such as oil, natural gas, wind, solar, thermal energy distributed the consumption of energy in different sectors. Rich countries (USA, European countries and China) discovered many sources due to the latest technologies and agreed to control harmful emissions. For this, 195 countries committed the Paris agreement to reduce CO_2 emissions by 40–70% by the year 2050 (He 2015). The Paris agreement is more important than Kyoto which includes both rich and poor nations to cut emissions involving India and China, the third largest polluters of the world. For this, Mr. Trump withdrew the Paris agreement because of treaty agreement, requires ratification by the Senate, and said that the US Government is working to develop farsighted climate change policy (Davenport 2017). The developing nations are still facing problems in producing energy due to unavailability of modern expertise and technologies and needs to use cheap sources. Consequently, the conversion from coal to gas and oil for power creation began occurring at a large scale. Currently, the oil price is higher than the coal cost in energy production. Consequently, presently, this shift over from oil to coal will decline the price of creation and an economic shortfall in Pakistan. Furthermore, various industrialized and emerging nations have previously returned to coal. Wolde-Rufael (2010) tested that the coal assets of the globe will finish in around 147 years while resources of oil and gas will finish in around 41 years and 63 years correspondingly. Therefore, due to long-life coal resources, the demand will rise over a future period. The total world coal ingestion grew by 3731.5 Mtoe by 1% in 2017 after 2-year decline. In 2015 and 2016, coal demand decreased by 2.3% and 2.1% because of lower demand in power sectors in key markets of China and the USA. In 2017, coal consumption increased by 3.5 per cent in electricity generation than in previous years (IEA 2018). Moreover, coal consumption will rise to 28 per cent in 2030 (Energy Information Administration 2009). Pakistan is among average humanoid established nations in the major areas such as global, regional and national Human Development (Human Development Report 2013). Pakistan has much coal reserve but still using furnace oil and natural gas in maximum power generation (Abas et al. 2017). Coal can be considered an adequate alternative to maintain continuous development in Pakistan, due to its competitive cost and also due to its available reserves (Lin and Raza 2019; Raza et al. 2019).

The analysis in this research study pursues to realize the perilous aspects determining Pakistan's coal consumption to evaluate economic growth and energy-related estimations. We have taken gross domestic product (GDP), coal consumption, unemployment, population, services value added (SVA) and fiscal deficit with a multivariate structure. These factors raise the whole efficiency as of their effect on the scale of economics, and other consequences for example services, the performance of employees, management abilities, production capacity and transfer of technology. According to Grossman and Helpman (1990) and Rivera-Batiz and Romer (1991), these factors, furthermore, permit for better use of assets and do not distinguish the local marketplace.

This study proposes a robust model to study the association between coal use and economic development in Pakistan. Additionally, the application of new approximation methods such as ARDL, VECM, Ng–Perron test, CUSUM and CUSUM square allows us to confirm the robustness of the outcomes. In light of the above discussion, researchers have examined that coal utilization is the most important and cheap power generation source which can take out Pakistan from the acute energy crisis. It is, therefore, by using all the explained coal resources, the production cost may come down and it will automatically add economic value. In this study, our objective is related to the literature on the association between economic development and coal utilization and related affecting factors (see Table 3). This research is based on time data investigation during 1981–2017. The estimations include coal consumption, GDP, population, unemployment, fiscal shortfall and service division to find out the causalities among the factors. Earlier studies considered labour, economic growth, urban population and coal consumption which are different from this article. This study is unique, including domestic factors such as GDP, coal consumption, rural–urban unemployment, fiscal deficit, service values and rural–urban population in Pakistan. Besides, energy intensity increases because of the shifting of individuals from rural–urban areas that are associated with huge level actions of the employment force (Sadorsky 2013).

Section 2 includes the literature review. Section 3 is based on method. Section 4 includes the experimental discussion, while Sect. 5 is based on outcomes and policy suggestions.

2 Literature review

Various investigations have identified the causal association among coal utilization and financial development factors from Pakistan and different countries by applying different approaches. Energy efficiency technologies and low price of energy services play a positive effect and give sustainability to energy. For this Alvi et al. (2018), the estimated energy efficiency and residential electricity consumption by applying the magnitude of the direct rebound effect, co-integration and error correction model (ECM) during 1973–2016. The outcomes show that power utilization is growing in Pakistan in short and long run beneath climate fluctuations. Zhang et al. (2017) estimated clean vitality ingestion, total fuel utilization and fiscal development and carbon dioxide (CO_2) emanations in Pakistan by applying the environmental Kuznets curve (EKC) and ARDL method during 1970–2012. The results show that renewable energy plays a dominant role in reducing carbon dioxide emission, and non-renewable energy consumption is the main culprit in promoting carbon dioxide emission. Therefore, energy safety is significant for short-run and long-run socio-economic and ecological sustainability. In particular, Bekun et al. (2019) found that non-renewables increase CO_2 emissions while renewables cause the opposite effect. The results on energy and economics proposed by Nawaz and Alvi (2018) are based on Johansen co-integration, Granger causality and VECM. They found that power insecurity is destructive for the atmosphere and socio-economic conditions in Pakistan. Additionally, expansion of humanoid wealth will lessen carbon emanations in Pakistan without diminishing monetary development (Bano et al. 2018).

Different single- and multi-country studies are summarized in Tables 1 and 2, respectively. The empirical literature reviews causal association among coal ingestion and fiscal growth of Pakistan, China, India and other multiple countries using different approaches. Empirical examinations on the causality between coal utilization and monetary development in Pakistan are restricted and assumed in the literature. Because of the economic crisis, energy disaster, industrial growth and population could be harmful in reducing the GDP of Pakistan. It is, therefore, energy plays an essential part in the sustained financial growth of a country. Consumption of energy is an indicator to assess the living standard of people, economic culture and economic growth of a country (Anwar 2016; Lin and Raza 2019). In many countries, coal-fired power generation remains crucial in the foreseeable future to cover base load demand. Pakistan consumes electricity, coal, oil and natural gas. According to Pakistan Energy Yearbook (2018), the overall primary commercial energy supply mix was increased by 8.4% than the previous year 2017. The share of each energy product during 2018 in primary energy supply was 31.2% of oil, 34.6% gas, 8.7% imported LNG, 1.2% LPG, 12.7% coal, 7.7% hydroelectricity, 2.7% nuclear electricity, 0.1% imported electricity and 2.7% electricity. During 2018, the primary commercial energy supplies have increased from 80 to 86 Mtoe. The analysis shows that the final energy consumption was enhanced by 9.7% and reached to 50–55 Mtoe during 2017–2018. It was due to the maximum utilization of the industrial, agriculture and transport sectors. The gap between energy supply and energy demand is 31.308 Mtoe in which Pakistan import 41.525 Mtoe energy from various countries. The total primary energy supply has increased by 8.4%, while total primary energy consumption of Pakistan has increased by 9.7% because of import (LPG, LNG, imported electricity) and major consumption in industry, transport and agriculture sector. Thus, the import bill has increased by 9.1 billion $US in 2017 and 11.9 billion $US in 2018 which is not supportive of the economy of Pakistan. Additionally, the total proved reserves of coal in Pakistan are 185.175 billion tons. This can be used for cheap energy creation. Therefore, the Government of Pakistan has explored coal assets in Baluchistan, Punjab, KPK and AJK having warming esteem of 9000–15,000 Btu/LB (Lin and Raza 2019). For this, Pakistan has signed coal energy project worth of 7560 MW and renewable energy with the capacity of 2790 MW with CPEC. According to Tables 1 and 2, this study gives coal-related energy consumption in Pakistan by using data of 1981–2017 that have not been studied before. Literature noted that coal consumption has boosted GDP, electricity production in both the short-run and long-run period but particularly in advanced nations, for example, China, UK, the USA, OECD, India and Korea. It is, therefore, this study attempts to find out the outcomes of coal consumption including various factors as mentioned in Table 3. The main motivation and contribution of this study are to assess the relationship between coal consumption and related factors that can lead the economy of Pakistan during 1981–2017. This will explore and move towards development and satisfy the national and commercial needs of a country. Different testing techniques unit root test, autoregressive distributed lags model, vector error correction model granger causality would be better to inspect the short-run and long-run causalities and co-integration among the factors. The outcomes would be better for the economic development and energy efficiency, which are presented in Sect. 4.

Table 1 Literature of individual countries with causalities

References	Country and period	Variables	Methods	Causality
Ahmed et al. (2015)	Pakistan; 1971–2011	EC and EG	GC	EG ⟶ EC
Alam and Butt (2002)	Pakistan; 1960–1998	EC, labour and capital, EG	ECM (J&JT)	EC ⟷ EG; C ⟶ EC, L&C C ⟶ EG
Anastasiu et al. (2018)	Romania; 2007–2016	Coal reserves and electricity production	Romanian coal and energy sector model	Coal reserves ⟶ urban–rural areas
Apergis and Payne (2010a, b)	Greece; 1980–2006	CC and EG	Panel co-integration test	CC ⟷ EG
Aqeel and Butt (2001)	Pakistan; 2001	EC and EG	Co-integration and HVGC	EC ⟶ EG; EG ⟶ FC; energy ⟶ EG; EC ⟶ employment
Bhattacharya et al. (2015)	China; 1978–2010	CC and EG	ARDL	CC ⟶ EG; coal electricity ⟶ GDP
Bloch et al. (2012)	Pakistan; 1965–2008	GDP and CC	VECM, IAT	GDP CC
Chen et al. (2018)	China; 2000–2015	Urban–rural residential and CC	LMDI	Urban–rural residential ⟶ CC
Chong et al. (2015)	China; 2001–2011	CC and EG	LMDI	CC ⟶ EG; EE ⟶ industrial output
Khan and Ahmad (2008)	Pakistan; 1972–2007	Electricity, CC and EG	VECM, co-integration	Income, gas consumption ⟶ electricity and CC
Khan and Qayyum (2009)	Pakistan; 1970–2006	coal, oil, gas, LPG, electricity, EG	ARDL	CC ⟷ EG
Komal and Abbas (2015)	Pakistan; 1972–2012	FD, CC and EG	GMM technique	EG ⟶ EC; energy prices ⟶ EC; FD ⟶ EG
Kumar and Shahbaz (2012)	Pakistan; 1971–2009	CC, labour market and EG	ARDL, VECM, GC	CC EG
Kurniawan and Managi (2018)	Indonesia; 1970–2015	CC, urbanization and trade openness	ARDL	Urbanization and trade openness ⟶ CC
Li and Leung (2012)	China; 1953–2007	CC and EG	Panel unit root and short- and long-run co-integration	CC ⟷ GDP; GDP ⟶ CC
Lin et al. (2018)	China; 2010–2015	Coal peak and CO_2 emissions	LBNLs	CC ⟶ electricity and CO_2 emissions
Muhammad et al. (2013)	Pakistan; 2001–2012	EG, EC	ADF, GCT and ARDL	EC ⟶ EC
Rehman et al. (2019)	Pakistan; 1990–2015	Coal, electricity, Pak-times	Energy optimization model	Coal energy ⟶ GHG emissions
Shahbaz et al. (2012)	Pakistan; 1972–2011	RE, NRE, EG, C&L	ARDL and Cobb–Douglas	RE, NRE, C&L ⟶ EG
Shahbaz and Dube (2012)	Pakistan; 1972–2009	CC and EG	ARDL, VECM, GC	CC ⟷ EG
Xu et al. (2018)	China; 1953–2013	CC, GDP	Cobb–Douglas	CC ⟶ EG; EI ⟶ CC;
Yoo (2006)	Korea; 1968–2002	EC and EG	ECM, unit root test	CC ⟷ EG

Table 1 (continued)

References	Country and period	Variables	Methods	Causality
Zhang et al. (2018)	China; 1991–2013	CC and EG	LMDI	EAE and population ⟶ CC
Zhao and Luo (2018)	China; 1991–2015	Coal, gases, emissions	Concentration on variables literature	CC ⟶ emit gases

Arrow direction and their purpose are given in abbreviations

Table 2 Literature of multiple countries

References	Country and period	Variables	Methods	Causality
Apergis and Payne (2010a, b)	OECD; 1980–2005	CC and EG	VECM, Granger causality	CC $\longleftrightarrow$ EG
Bildirici and Bakirtas (2014)	India, Brazil, Russian, China, Turkey and South Africa; 1980–2011	EG, coal, natural gas and oil consumption	ARDL	CC $\longleftrightarrow$ EG (China and India)
Lei et al. (2014)	USA, China, India, Germany, Russia and Japan; 2000–2010	CC and EG	Panel causality and VECM	CC $\longleftrightarrow$ EG (Germany, Russia and Japan); EG $\longrightarrow$ CC (China); CC $\neq$ EG (USA and India)
Shahbaz et al. (2014)	47 developing and developed countries; 1965–2010	CC	LM	CC $\longrightarrow$ stationery in all countries
Zahid (2008)	Pakistan, India, Sri Lanka, Bangladesh and Nepal; 1971–2003	Coal, GDP	ECM, Granger causality	CC $\longrightarrow$ GDP

Table 3 Descriptions of variables

Variables	Unit	Sources
Coal consumption	Mtoe	(SRWE 2018)
GDP per capita	Current $US	(SRWE 2018)
Services value added	Constant LCU	(SRWE 2018)
Overall fiscal deficit	% of GDP	PES
Unemployment rural	Mln.	PES
Unemployment urban	Mln.	PES
Population rural	Mln.	PES
Population urban	Mln.	PES

The variables (given in Table 3) described measuring the strength and effects. Each variable influences Pakistan's economy from either urban or rural areas

In Table 1, concerning the individual countries' connection concerning coal utilization and financial development is condensed. The literature on the causal association among GDP, coal consumption, rural–urban unemployment, rural–urban population, fiscal deficit and service values is too small in comparison with literature concerning coal utilization and economic development. In Table 2, the literature of various countries that show the causal association between coal, financial development, oil and flammable gas utilization is given.

3 Data sources and methods

In this section, the data collection and methods of data calculation on the proposed topic are presented.

3.1 Data collection

The data for the eight variables (Table 3) have been collected from different sources, for the period 1981–2017. The data of GDP per capita and services values added were collected from world development indicators while coal utilization statistics from (Statistical Review of World Energy 2018). Rural–urban population, rural–urban unemployment and fiscal deficit data have been collected from the several volumes of Pakistan Economic Surveys. Data information is provided in Table 3. Figure 1 shows the variables contribution to Pakistan's economy. In the services sector, the rural–urban population has contributed in GDP by 402.73%, 66.50% and 58.89% during 2017, while in the overall fiscal deficit, rural–urban unemployment has contributed by 23.93%, 10.73% and 6.39% in the GDP of Pakistan. Finally, coal has contributed by 26.69% in GDP during 2017. Coal is the third energy-consuming source after gas and oil in Pakistan which has contributed by 12.7% during 2017–2018 (Pakistan Energy Yearbook 2018). Also, the major energy-consuming sectors are agriculture, industrial and transport sectors which have contributed by 18.86%, 20.91% and 13.04%, respectively, in GDP of Pakistan. Due to the maximum import of fossil fuel, Pakistan should utilize its energy resources such as coal and renewable energy resources which will not only benefit GDP but also reduce the energy crisis in Pakistan. By applying coal-related resources, the cost of production may come down, and this will ultimately contribute to the maximum economic growth of Pakistan.

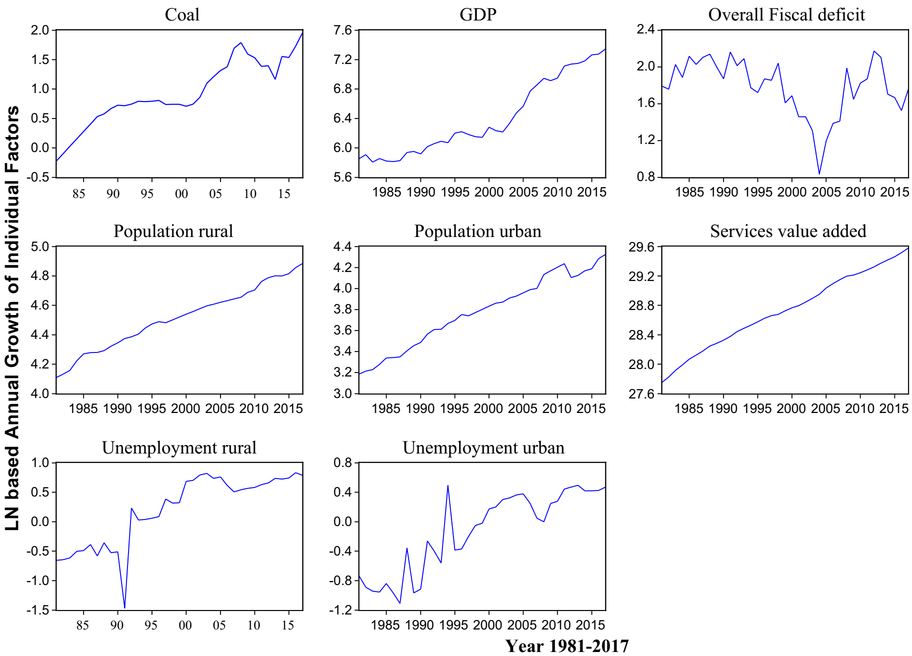

Fig. 1 The annual development rate of various factors and their contribution to economic development during 1981–2017

Thus, this study motivates us to where coal consumption is the most significant and economical energy source of Pakistan which has reserves of 185.175 billion tons. Growths of various factors have a positive influence on the economy of Pakistan.

3.2 Methodology

Log linear model has been utilized to check out the influence of coal utilization, unemployment, population, services value added and fiscal deficit on the financial development in Pakistan perspective. The observed equation model is as follows:

$$\ln GDP_{\mathrm{t}} = \alpha_{\mathrm{i}} + \alpha_{\mathrm{c}} \ln \mathrm{CC}_{\mathrm{t}} + \alpha_{\mathrm{u-r}} \ln U - R_{\mathrm{t}} + \alpha_{\mathrm{u-u}} \ln U - U_{\mathrm{t}} + \alpha_{\mathrm{P-r}} \ln P - R_{\mathrm{t}} + \alpha_{\mathrm{P-u}} \ln P - U_{\mathrm{t}} + \alpha_{\mathrm{fd}} \ln \mathrm{FD}_{t} + \alpha_{\mathrm{sva}} \ln \mathrm{SVA}_{\mathrm{t}} + \mu_{\mathrm{i}}, \quad (1)$$

where $\mathrm{GDP}_{\mathrm{t}}$ is the real per capita GDP, CC_t is the coal consumption, $\mathrm{U–R}_{\mathrm{t}}$ is unemployment in rural areas, $\mathrm{U–U}_{\mathrm{t}}$ is the unemployment in urban areas, $\mathrm{P–R}_{\mathrm{t}}$ is the rural populace, $\mathrm{P–U}_{\mathrm{t}}$ is the urban population, FD_{t} is the overall fiscal deficit and $\mathrm{SVA}_{\mathrm{t}}$ is the services value added.μ_{i} is the error term, natural log (ln) and α_{i} is the intercept.

3.3 Model description

The random walk problematic has been estimated in the present data series by estimating unit root test and testing the misrepresentations in the size of the error term (Pesaran et al.

2001). NGP test shows the order of integration of available statistics and effective modification of unit root tests (Fedorová 2016). Equations (2)–(5) show the purpose of this test. NGP test chains generalized least square (GLS) de-trending with standard deviation (SD) to design a new test. The given tests are based on four tests such as MZ_{α}, MZ_{t}, MSB and MPT

$$\overline{\mathrm{MZ}}_{\alpha} = T^{-1}y_t^d - \hat{\lambda}^2\left[2T^{-2}\sum_{t=1}^{T} y_{t-1}^d\right]^{-1}, \tag{2}$$

where y_{t}^d is the de-trending value and $\hat{\lambda}^2$ is a consistent estimate of λ^2. λ^2 has imperative implications for the limited sample for the efficient PP test and focused that an autoregressive evaluation of λ^2, and ought to be used to achieve stable limited sample size (Pesaran et al. 2001). In this way, they prescribed evaluating λ^2 from the augmented Dickey–Fuller (ADF) test dependent on GLS de-trending information

$$\overline{\mathrm{MSB}} = \left[\frac{T^{-2}\sum_{t=1}^{T} y_{t-1}^d}{\hat{\lambda}^2}\right]^{-1/2}, \tag{3}$$

$$\overline{\mathrm{MZ}}_{\mathrm{t}} = \overline{\mathrm{MZ}}_{\alpha} \times \overline{\mathrm{MSB}}, \tag{4}$$

where

$$\hat{\lambda}^2 = \left(\sum_{t=p+1}^{T} \varepsilon_t^2\right)\left[(T-k)\left(1-\sum_{t=1}^{p} y_{t-1}^d \hat{\beta} i\right)^2\right]^{-1}. \tag{5}$$

MZ_{α}, MZ_{t} are effective forms of the PP; Z_{α} and Z_{t} tests in littler size twists and particularly in the presence of negative moving average mistakes. It is, due to the de-trending procedure, it turns out to be stronger than conventional unit root tests, and for example, Dickey and Fuller (1981) ADF test and PP test Phillips and Perron (1988). In the unit root simulation, MZ_{α} and MZ_{t} are modified by Elliott et al. (1996), Pesaran et al. (2001) and Shahbaz et al. (2013), while MSB test was proposed by Elliott et al. (1996). In this study, the researcher will discover the long-run association among stated variables (coal ingestion, unemployment, population, economic shortfall and services sector development on the economic development in Pakistan) by estimating ARDL bounds test established by Pesaran et al. (2001). VECM Granger causality and ARDL bounds test analysis have been conducted to find out the situation of this research

$$\begin{aligned}
\Delta \ln \mathrm{EG}_{\mathrm{t}} = {} & \alpha_{c11} + \alpha_{11}\ln \mathrm{EG}_{t-1} + \alpha_{12}\ln \mathrm{CC}_{t-1} + \alpha_{u-r13}\ln U - R_{t-1} + \alpha_{u-u14}\ln U - U_{t-1} \\
& + \alpha_{P-r15}\ln P - R_{t-1} + \alpha_{P-u16}\ln P - U_{t-1} + \alpha_{fd17}\ln \mathrm{FD}_{t-1} + \alpha_{sva18}\ln \mathrm{SVA}_{t-1} \\
& + \beta_{11}\sum_{i=1}^{p}\Delta\ln \mathrm{EG}_{t-i} + \beta_{12}\sum_{i=0}^{p}\Delta\ln \mathrm{CC}_{t-i} + \beta_{13}\sum_{i=0}^{p}\Delta\ln U - R_{t-i} + \beta_{14}\sum_{i=0}^{p}\Delta\ln U - U_{t-i} \\
& + \beta_{15}\sum_{i=0}^{p}\Delta\ln P - R_{t-i} + \beta_{16}\sum_{i=0}^{p}\Delta\ln P - U_{t-i} + \beta_{17}\sum_{i=0}^{p}\Delta\ln \mathrm{LFD}_{t-i} \\
& + \beta_{18} + \sum_{i=0}^{p}\Delta\ln \mathrm{SVA}_{t-i} + \mu_i,
\end{aligned} \tag{6}$$

where Δ is the distinction operator. As indicated by Morley (2006), the causal relationship will occur, if there is a long-run association among factors. To evaluate the short-run and long-run causation amid coal utilization and monetary development, we apply VECM Granger causality estimation as indicated in Eq. (7)

$$\begin{bmatrix} \Delta\text{LNEG}_{\text{it}} \\ \Delta\text{LNCC}_{\text{it}} \\ \Delta\text{LNU}-R_{\text{it}} \\ \Delta\text{LNU}-U_{\text{it}} \\ \Delta\text{LNP}-R_{\text{it}} \\ \Delta\text{LNP}-U_{\text{it}} \\ \Delta\text{LNFD}_{\text{it}} \\ \Delta\text{LNSVA}_{\text{it}} \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \\ \delta_7 \\ \delta_8 \end{bmatrix} + \sum_{p-1}^{q} \begin{bmatrix} \theta_{11P}\theta_{12P}\theta_{13P}\theta_{14P}\theta_{15P}\theta_{16P}\theta_{17P}\theta_{18P} \\ \theta_{21P}\theta_{22P}\theta_{23P}\theta_{24P}\theta_{25P}\theta_{26P}\theta_{27P}\theta_{28P} \\ \theta_{31P}\theta_{32P}\theta_{33P}\theta_{34P}\theta_{35P}\theta_{36P}\theta_{37P}\theta_{38P} \\ \theta_{41P}\theta_{42P}\theta_{43P}\theta_{44P}\theta_{45P}\theta_{46P}\theta_{47P}\theta_{48P} \\ \theta_{51P}\theta_{52P}\theta_{53P}\theta_{54P}\theta_{55P}\theta_{56P}\theta_{57P}\theta_{58P} \\ \theta_{61P}\theta_{62P}\theta_{63P}\theta_{64P}\theta_{65P}\theta_{66P}\theta_{67P}\theta_{68P} \\ \theta_{71P}\theta_{72P}\theta_{73P}\theta_{74P}\theta_{75P}\theta_{76P}\theta_{77P}\theta_{78P} \\ \theta_{81P}\theta_{82P}\theta_{83P}\theta_{84P}\theta_{85P}\theta_{86P}\theta_{87P}\theta_{88P} \end{bmatrix} \times \begin{bmatrix} \Delta\text{LNEG}_{\text{it}-1} \\ \Delta\text{LNCC}_{\text{it}-1} \\ \Delta\text{LNU}-R_{\text{it}-1} \\ \Delta\text{LNU}-U_{\text{it}-1} \\ \Delta\text{LNP}-R_{\text{it}-1} \\ \Delta\text{LNP}-U_{\text{it}-1} \\ \Delta\text{LNFD}_{\text{it}-1} \\ \Delta\text{LNSVA}_{\text{it}-1} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \\ \alpha_8 \end{bmatrix} \text{ect}_{\text{it}-1} + \begin{bmatrix} \varepsilon_{1\text{it}} \\ \varepsilon_{2\text{it}} \\ \varepsilon_{3\text{it}} \\ \varepsilon_{4\text{it}} \\ \varepsilon_{5\text{it}} \\ \varepsilon_{6\text{it}} \\ \varepsilon_{7\text{it}} \\ \varepsilon_{8\text{it}} \end{bmatrix}, \quad (7)$$

where ($i=1$, …, 37) stands for number of states; t is 1981, …, 2017 which denotes the time duration; ε_{it} shows the predicted residual which describes deviations from the long-run association; α_{i} and θ_{i} permit for the possibility of a definite country fixed effect and show tendency, correspondingly; LN designates the natural logarithm alteration; δ_{i}, α_{i} and λ_{i} denote the elasticity of emissions with respect to GDP, coal consumption, rural–urban unemployment, fiscal deficit, service values and rural–urban population, respectively. $\text{ECT}_{\text{t}-1}$ is the error correction term. VAR is the vector autoregressive. Engle and Granger (1987) estimated VAR results at first differences which are not reliable. To improve the consistency of outcomes, Bannerjee et al. (1998) gave the lag term of vector error correction term (VECT) in the form of ARDL. The lagged VECT sign and inverse expose the changes from short- to long-run balance. Moreover, the research hypothesizes to create a strong relationship among factors. CUSUM and CUSUMQ are also applied to prove the structural solidity of our framework.

4 Estimation and results interpretation

This section includes the results and interpretations.

4.1 Discussion

Due to high prediction power, small data, consistency and efficient results of NGP test, PP and ADF unit root tests are not applied. Outcomes of the NPG experiment are given in Table 4. The outcome demonstrates that all the factors are stationary at first distinction with intercept and pattern. Furthermore, Table 4 reports the outcomes of Elliott et al. (1996) and Pesaran et al. (2001) unit root tests and checks the presence of unit root in $lnGDP_t$, $lnCC_t$, $lnU{-}R_t$, $lnU{-}U_t$, $lnP{-}R_t$, $lnP{-}U_t$, $lnFD_t$ and $lnSVA_t$ at level and stationary at first level. However, none of the variable integrated at I(2), so we persuaded the ARDL bounding approach

$$H_0 : (\theta_1) \neq (\theta_2) \neq (\theta_3) \neq (\theta_4) \neq (\theta_5) \neq (\theta_6) \neq (\theta_7) \neq (\theta_8), \tag{8}$$

$$H_a : (\theta_1) = (\theta_2) = (\theta_3) = (\theta_4) = (\theta_5) = (\theta_6) = (\theta_7) = (\theta_8). \tag{9}$$

The null hypothesis (H_0) of the unit root among the existing variables is not rejected for level series but is rejected for the first order (significant at the 1% level). As all the variables are integrated of order one, i.e. I(1), the ARDL model can be applied. In Table 4, Δ is the difference operator of the variables and p represents the optimal lag lengths. Similarly, in Table 5, we have calculated the H_0 of no co-integration which is tested against H_a. For this, we use *F*-statistics and *T*-statistics, regardless of the series integrated I(0) of I(1). Furthermore, statistics assumptions are presented in note 2. The arrangements have a comparative order and review the long-run association between all elements by applying ARDL bounds. For this, a lag length (p − 1) due to the VECM condition was utilized. The aim is to compute the existence of co-integration. Table 5 shows the calculated values of *F*-statistics and *T*-statistics at lower and upper critical bounds with 5% and 10% level. Some diagnostics variables (DW-stat, serial correlation, normality, heteroscedasticity) are also applied to check the functionality of a model which shows correct results. *F*-statistics is 2.5743 while *T*-statistics is −2.2192 with the statistical significance at 5% level, indicating the existence of long-run co-integration between the factors. Durbin–Watson (DW) statistics is 0.8029 which estimates the presence of positive autocorrelation. These diagnostic tests, such as, serial correlation, heteroscedasticity, and normality measured after *F*-test and show that there is no serial correlation. The insignificance of heteroscedasticity approves that error terms are showing homoscedasticity. Finally, the insignificance of normality illustrates that the residuals are normally distributed. The probability of the model specification test does not reject the null hypothesis, confirming that the model is properly specified. The results are clear that economic development, coal utilization, joblessness,

Table 4 Unit root analysis

D.V.	I(0)				D.V.	I(1)			
	MZ_α	MZ_t	MSB	MPT		MZ_α	MZ_t	MSB	MPT
Ng–Perron test statistics									
$lnGDP_t$	−2.93452	−1.12785	0.38434	28.7982	$\Delta lnGDP_t$	−17.3812*	−2.94787	0.16960	5.24341
lnC_t	−5.96377	−1.70771	0.28635	15.2540	ΔlnC_t	−17.2433*	−2.86712	0.16627	5.69481
$lnU{-}R_t$	−15.5770	−2.76811	0.17771	5.98362	$\Delta lnU{-}R_t$	−20.5668*	−3.20559	0.15586	4.43784
$lnU{-}U_t$	−17.1283	−2.91259	0.17005	5.40322	$\Delta lnU{-}U_t$	−13.8377*	−2.63025	0.19008	6.58597
$lnP{-}R_t$	−6.17983	−1.75370	0.28378	14.7426	$\Delta lnP{-}R_t$	−16.3294*	−2.84578	0.17427	5.64951
$lnP{-}U_t$	−9.70211	−2.19532	0.22627	9.42302	$\Delta lnP{-}U_t$	−19.5087*	−3.12012	0.15994	4.68953
$lnFD_t$	−9.95599	−2.22184	0.22317	9.19402	$\Delta lnFD_t$	−16.0116*	−2.79988	0.17487	5.86600
$lnSVA_t$	−8.80819	−2.07920	0.23605	10.4147	$\Delta lnSVA_t$	−12.0875*	−2.36555	0.19570	8.02486

*Significance level at 1%

Table 5 ARDL bounds testing analysis

Estimated models				$LEG_t = f(LCC_t + LU-R_t + LU-U_t + LP-R_t + LP-U_t + LFD_t + LSVA_t)$
Optimal lags (*p*)				(1, 0, 0, 1, 0, 0, 0, 1)
Statistics				*F*-stat, *T*-stat, DW-stat, serial correlation, normality, heteroscedasticity
Significance level	Critical bonds for *F*-test		Critical bonds for *T* test	
	LCB	UCB	LCB	UCB
5%	2.32	3.5	−2.86	−4.57
10%	2.03	3.13	−2.57	−4.23
F-statistics	2.5743		*T*-statistics	−2.2192
DW-statistics	0.8029		Heteroscedasticity	2.3674 [0.0392]
Normality	1.0930 [0.5789]		Serial correlation	0.4370 [0.7065]

ARDL bounds test is based on different diagnostics tests. In *F*-statistics; if *F*-value is below lower bound than accept the null hypothesis (H_0) (this shows no co-integration between the factors when GDP is D.V.) and if *F*-value is higher than UCB than reject the H_0. In the lower critical bound, the H_0 is not rejected, while upper critical bound rejected the H_0. This shows that there is a co-integration between factors when GDP is the dependent variable. In the *T*-statistics, at LCB there is no co-integration at upper critical bound when GDP is dependent variable (D.V.) than there is a co-integration amid the variables

*LCB shows lower critical bound, while UCB measures upper critical bound

population, financial shortage and services value added are co-coordinated and having a long-run association.

4.2 VECM Granger causality analysis (GCA)

Error correction term (ECT) was tested to estimate the long-run connection among the elements. The equation of our model is given as:

$$\begin{aligned} \mathrm{ECT}_{t-1} = {} & \ln \mathrm{EG}_{t-1} + \ln \mathrm{CC}_{t-1} + \ln U - R_{t-1} + \ln U - U_{t-1} + \ln P - R_{t-1} \\ & + \ln P - U_{t-1} \ln \mathrm{FD}_{t-1} + \ln \mathrm{SVA}_{t-1} + c. \end{aligned} \tag{10}$$

Granger (1969) suggested the causalities based on co-integration. For this, VECM Granger causality is the best way to measure causalities among the variables. For example, Khan and Ahmad (2008) for Pakistan, Apergis and Payne (2010a, b) for OECD countries and Lei et al. (2014) for multiple developed countries measured the VECM of individual variables based on coal consumption and economic growth. Table 6 indicates the short-run and long-run VECM Granger causalities of individual variables. In the short run, the result found that there is a bidirectional causative association among GDP and coal utilization. This result is consistent with the present studies Bloch et al. (2012), Li and Leung (2012), Kumar and Shahbaz (2012), Shahbaz and Dube (2012), Apergis and Payne (2010a, b), Zahid (2008), Lei et al. (2014) and Bildirici and Bakirtas (2014). Furthermore, also found bidirectional causalities (@ level of 1%, 5%) among unemployment, population and overall fiscal deficit. The value-added services are only

Table 6 The VECM GC analysis

D.V.	Short run								Long run
	$\Delta lnGDP_t$	ΔlnC_t	$\Delta lnU{-}R_t$	$\Delta lnU{-}U_t$	$\Delta lnP{-}R_t$	$\Delta lnP{-}U_t$	$\Delta lnFD_t$	$\Delta lnSVA_t$	ECM_{t-1}
$\Delta lnGDP_t$	–	0.01662***	0.4063*	−0.7907***	−0.0435***	−0.1304***	0.4625*	−0.0028***	−0.3118***
ΔlnC_t	0.1518*	–	−0.3058***	0.1344*	0.0059***	0.0347***	0.1006*	0.0017***	0.02516***
$\Delta lnU{-}R_t$	−0.0684***	−0.0131***	–	−0.3174***	0.0039***	−0.0165***	−0.0111***	−0.0116***	−0.03414***
$\Delta lnU{-}U_t$	0.0626**	−0.0509***	0.1812*	–	0.0005***	−0.0109***	−0.0849***	−0.0042***	−0.2555***
$\Delta lnP{-}R_t$	−0.4838***	1.3053	−0.1487***	−1.2967***	–	−0.8235***	2.6897	0.1954*	0.0094***
$\Delta lnP{-}U_t$	−0.6656***	1.004	−0.2138***	−1.8670***	0.0373***	–	−0.9990***	−0.0354***	−0.2260***
$\Delta lnFD_t$	−0.1964***	−0.0729***	−0.1983***	−0.2538***	0.0140***	0.0210***	–	−0.0091***	0.04255**
$\Delta lnSVA_t$	4.1126	0.4663*	10.3279	8.0115	−0.0340***	−0.6326***	4.2173	–	−0.1791***

Significance level at *10%, ** 5%, *** 1%

variables which have unidirectional causality with coal consumption and bidirectional causality among the rural–urban population in Pakistan. VECM GC long-run results are presented in Table 6 which shows that energy consumption has a maximum output and has a bidirectional relationship between them. The direction from CC to GDP and other factors is negative for long run at 1% and 5% levels. The results are consistent with existing studies for example (Satti et al. 2014). In the long run, economic development and coal use have an imperative bidirectional effect and the same is true with other variables. The results measure the granger causes among variables in both unidirectional and bidirectional. Even urban–rural unemployment, rural–urban populations have significant bidirectional causalities. There is bidirectional causation among fiscal deficit, utilization of coal and economic growth. Additionally, in the short run, the urban population causes economic growth, unemployment, coal consumption, services value added and fiscal deficit. This shows the direct relationship among variables which effects on Pakistan's economy. Urban population and fiscal deficit have a bidirectional fundamental liaison with coal consumption and similar is the rural population. The findings of Table 6 demonstrate one-sided causation is moving from the services sector to monetary progression. Additionally, cumulative sum (CUSUM) and a cumulative sum of squares (CUSUM) are reported in Figs. 2 and 3, respectively. The aim of taking these graphs is to examine the structural stability in the model. It clears that the lines fall between 95% critical bound for both cases we conclude there is no sign of structural instability in our model. Thus, the critical lines suggest that our model is stable and can be used for policy implications. In the end, researchers have not found any structural unpredictability over the given time by applying the CUSUM and CUSUM square which are shown in Figs. 2 and 3, respectively.

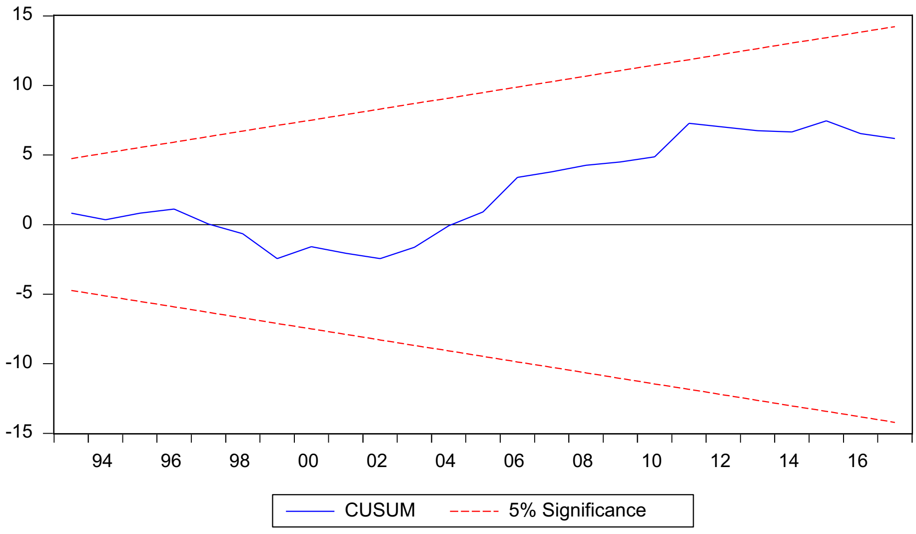

Fig. 2 Cumulative sum shows critical bounds at 5% level. The *x*-axis shows the period from 1981 to 2017, while *y*-axis line shows the measurement points (CUSUM and CUSUMQ show the structural brakes; either model is stable or not. The model shows stability in Figs. 2 and 3)

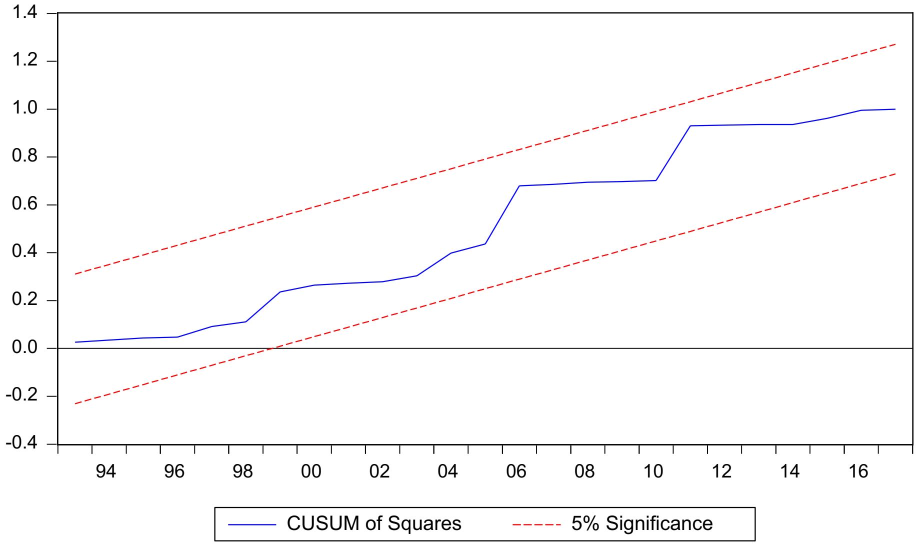

Fig. 3 CUSUM squares show critical bounds at the level of 5%. The *x*-axis shows the period from 1981 to 2017, while *y*-axis line shows the measurement points

5 Conclusion and policy suggestions

5.1 Conclusion

Energy availability has become the primary concern of the world. During the last 4 decades, the world has changed its focus from imported expensive energy resources to cheap resources either renewable or non-renewable that also bring socio-economic and environmental sustainability. This research attempted to assess the time-varying relationship between coal utilization and economic development with the additional factors, for example, rural unemployment, urban unemployment, rural population, urban population, overall fiscal deficit and services value added in case of Pakistan. This exploration means to lead a novel study to satisfy energy needs and the coal utilization by satisfying quick developing national and commercial demand of the developing nation.

To do so, we used NPG, ARDL and VECM Granger causality testing approach to inspect the causalities in short-run and the long-run association among the elements during 1981–2017. VECM Granger causality technique is used to detect the direction of causality among the selected variables. Some robust tests are also used to guarantee the stability of the model. ARDL bounds testing approach to investigate co-integration association between variables by applying LCB and UCB analysis. The estimation results give clear evidence that the effect of coal consumption on economic development is economical and efficient for the country. The results show the co-integration between all variables in both short run and long run. In the short run, the urban population causes economic growth, unemployment, coal consumption, services value added and fiscal deficit. Urban population and fiscal deficit have a bidirectional causative linkage with coal, and similar is the rural population. Monetary developments in the long term and coal utilization have a significant bidirectional effect. The same is also true for the remaining variables. The findings of this study have bidirectional causation among economic development and coal utilization in the short and long run, and both are complementary to one another.

5.2 Policy recommendations

Having an active role in the vitality mix and an important growing trend of coal utilization, Pakistan must use coal to improve energy security. Pakistan imported 13.782 Mtoe oil products, 7.492 Mtoe LNG and 9.003 Mtoe coal in 2017–2018, which cost 10,782.73 million dollars (Pakistan Economic Survey 2018). This enormous energy imports spending and reliance, if lessened, will have an optimistic impact on Pakistan's economy. This will benefit from the economy in four ways: CO_2 (carbon dioxide) emissions will decrease, the value of imported fuel will decrease, renewable energy resources of the country will improve and available huge resources can be utilized such as coal which has reserves of 185.175 billion tons in Pakistan. This will not only improve the economy and economic culture but also lead to improving energy security.

Our outcomes additionally conclude that urbanization and income crucial variables in coal consumption are effective for Pakistan. Firstly, Pakistan should make alternative and economic power resources such as coal, and coal energy technologies give a path to economic development. According to Çoban and Yorgancılar (2011), coal-based plants are carbon emitters but cheap energy producers. In an emerging nation such as Pakistan, such natural resources, i.e. coal with modern technologies, can enhance power production and can also be useful in nearby and multinational companies in Pakistan (Shahbaz et al. 2013). This will improve employment, cost reduction and long-term sustainability. Secondly, give preference to economic development in applying various techniques. According to our analysis, a quick GDP improvement relies upon coal energy-intensive utilization. Thirdly, concentrate on the research and development (R&D), end-use combustion coal's proficiency, the transformation of energy efficiency, and greenhouse gas- and less CO_2-emitting advancements to improve the proficiency of coal. Fourthly, Pakistan should focus on indigenously available resources which are rich like coal in provinces of Balochistan, Punjab, Sindh and KPK. This policy will ensure better socio-economic, economic development and energy enhancement of Pakistan. Fifthly, the cost of coal power generation is lower than other resources in Pakistan Vision 2035 (2014). For this, Munir and Khan (2014) examined that vitality shortfall has brought about in monetary misfortunes among 2–3% of the GDP. Finally, the Alternative Energy Development Plan (AEDP), China Pakistan Economic Corridor (CPEC), Vision 2025 (2014), Vision 2035 (2014) and INDC 2015 projects are cost-effective and working for the enhancement of energy and economy of Pakistan because Pakistan is an energy-scarce country (Hydrocarbon Development Institute of Pakistan). Consequently, the utilization of energy plays an important part in the development of economic and culture of Pakistan. A few circumstances should be taken for Pakistan' vitality improvement, for example, coal power, sustainable power source and conducting energy effectiveness. We might want to propose Pakistan's investors in policy on some important notes. Firstly, appreciate overseas investments which bring coal technologies. Secondly, encourage the exchange of innovation from modern countries' coal clean technology to national firms.

5.3 Future purpose of the study

The analysis of our research is clear that the effect of coal consumption on economic development is economical and efficient for the country. The results show a bidirectional association between CC and EG and have many implications for policymakers, forecasters and analyst. A higher level of economic growth leads to higher energy demand. In the under developing countries such as Pakistan should encourage technology, energy resources, and encourage the policies related to energy efficiency, economic growth, and minimizes the cost of import and improve the income of individuals. In addition, our study includes ECM which gives reliable results for both short run and long run. Therefore, our findings are consistent expecting CC enhances EG. Thus, in the case of Pakistan, indigenous resources are more effective for socio-economic development and energy efficiency.

5.4 Limitations

Concerning our study, we have some limitations. Technology division, energy security, energy cost, R&D and external environmental factors are future concentrations. The financing and institutional preparations must be strengthened to accelerate the growth of sustainable and low-carbon technologies.

References

Abas, N., Kalair, A., Khan, N., & Kalair, A. R. (2017). Review of GHG emissions in Pakistan compared to SAARC countries. *Renewable and Sustainable Energy Reviews, 80,* 990–1016.

Ahmed, M., Riaz, K., Khan, A. M., & Bibi, S. (2015). Energy consumption–economic growth nexus for Pakistan: Taming the untamed. *Renewable and Sustainable Energy Reviews, 52,* 890–896.

Alam, S., & Butt, M. S. (2002). Causality between energy and economic growth in Pakistan: An application of cointegration and error-correction modeling techniques. *Pacific Asia Journal Energy, 12,* 151–165.

Alvi, S., Mahmood, Z., & Nawaz, S. M. N. (2018). Dilemma of direct rebound effect and climate change on residential electricity consumption in Pakistan. *Energy Reports, 4,* 323–327.

Anastasiu, N., Simionescu, B. C., Popa, M. E., Mihai, M., Rusu, R. D., & Predeanu, G. (2018). Romanian coal reserves and strategic trends. *International Journal of Coal Geology, 198,* 177–182.

Anwar, J. (2016). Analysis of energy security, environmental emission and fuel import costs under energy import reduction targets: A case of Pakistan. *Renewable and Sustainable Energy Reviews, 65*(2016), 1065–1078.

Apergis, N., & Payne, J. E. (2010a). Coal consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy, 38*(3), 1353–1359.

Apergis, N., & Payne, J. E. (2010b). The causal dynamics between coal consumption and growth: Evidence from emerging market economies. *Applied Energy, 87*(6), 1972–1977.

Aqeel, A., & Butt, M. S. (2001). The relationship between energy consumption and economic growth in Pakistan. *Asia-Pacific Development Journal, 8,* 101–110.

Bannerjee, A., Dolado, J., & Mestre, R. (1998). Error-correction mechanism tests for cointegration in single equation framework. *Time Series Analysis, 19*(3), 267–283.

Bano, S., Zhao, Y., Ahmad, A., Wang, S., & Liu, Y. (2018). Identifying the impacts of human capital on carbon emissions in Pakistan. *Journal of Cleaner Production, 183,* 1082–1092.

Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO_2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Science of the Total Environment, 657,* 1023–1029.

Bhattacharya, M., Rafiq, S., & Bhattacharya, S. (2015). The role of technology on the dynamics of coal consumption–economic growth: New evidence from China. *Applied Energy, 154,* 686–695.

Bildirici, M. E., & Bakirtas, T. (2014). The relationship among oil, natural gas and coal consumption and economic growth in BRICTS (Brazil, Russian, India, China, Turkey and South Africa) countries. *Energy, 65,* 134–144.
Bloch, H., Rafiq, S., & Salam, R. (2012). Coal consumption, CO_2 emission and economic growth in China: Empirical evidence and policy responses. *Energy Economics, 34,* 518–528.
Chen, J., Wu, Y., Song, M., & Dong, Y. (2018). The residential coal consumption: Disparity in urban–rural China. *Resources, Conservation and Recycling, 130,* 60–69.
Chong, C., Ma, L., Li, Z., Ni, W., & Song, S. (2015). Logarithmic mean Divisia index (LMDI) decomposition of coal consumption in China based on the energy allocation diagram of coal flows. *Energy, 85,* 366–378.
Çoban, O. C., & Yorgancılar, F. N. (2011). Relationship between renewable energy consumption and sustainable economic growth: The case of Turkey. In *The 2011 Barcelona European academic conference Barcelona, Spain* (pp. 703–712).
Davenport, C. (2017). *Top Trump advisers are split on Paris Agreement on climate change*. New York: New York Times.
Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica, 49*(4), 1057–1072.
Elliott, G., Rothenberg, J., & Stock, J. (1996). Efficient tests for an autoregressive unit root. *Econometrica, 64*(4), 813–836.
Energy Information Administration. (2009). *Annual report 2008*. US Department of Energy.
Engle, R., & Granger, C. (1987). Co-integration and error correction: Representation, estimation and testing. *Econometrica, 55*(2), 251–276.
Fedorová, D. (2016). Selection of unit root test on the basis of length of the time series and value of a parameter. *STATISTIKA, 96*(3), 3.
Granger, C. W. J. (1969). Investigating causal relationships by econometric models and cross spectral methods. *Econometica, 37,* 424–438.
Grossman, G. M., & Helpman, E. (1990). Comparative advantage and long-run growth. *American Economic Review, 80,* 796–815.
He, J. (2015). China's INDC and non-fossil energy development. *Advances in Climate Change Research, 6,* 210–215.
Human Development Report. (2013). http://hdr.undp.org/sites/default/files/reports/14/hdr2013_en_complete.pdf.
Hydrocarbon Development Institute of Pakistan (HDIP), Islamabad. https://hdip.com.pk/contents.php?cid=32.
IEA. (2018). https://webstore.iea.org/coal-information-2018-overview.
Khan, M. A., & Ahmad, U. (2008). Energy demand in Pakistan: A disaggregate analysis. *The Pakistan Development Review, 47,* 437–455.
Khan, M. A., & Qayyum, A. (2009). The demand for electricity in Pakistan. *OPEC Energy Review, 33*(1), 70–96.
Komal, R., & Abbas, F. (2015). Linking financial development, economic growth and energy consumption in Pakistan. *Renewable and Sustainable Energy Reviews, 44,* 211–220.
Kumar, S., & Shahbaz, M. (2012). Coal consumption and economic growth revisited: Structural breaks, cointegration and causality tests for Pakistan. *Energy Exploration and Exploitation, 30*(3), 499–522.
Kurniawan, R., & Managi, S. (2018). Coal consumption, urbanization, and trade openness linkage in Indonesia. *Energy Policy, 121,* 576–583.
Lei, Y., Li, L., & Pan, D. (2014). Study on the relationships between coal consumption and economic growth of the six biggest coal consumption countries: With coal price as a third variable. *Energy Procedia, 61,* 624–634.
Lewandowska-Bernat, A., & Desideri, U. (2018). Opportunities of power-to-gas technology in different energy systems architectures. *Applied Energy, 228,* 57–67.
Li, R., & Leung, G. C. (2012). Coal consumption and economic growth in China. *Energy policy, 40,* 438–443.
Lin, J., Fridley, D., Lu, H., Price, L., & Zhou, N. (2018). Has coal use peaked in China: Near-term trends in China's coal consumption? *Energy Policy, 123,* 208–214.
Lin, B., & Raza, M. Y. (2019). Analysis of energy related CO_2 emissions in Pakistan. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.02.112.
Morley, B. (2006). Causality between economic growth and migration: An ARDL bounds testing approach. *Economic Letters, 90,* 72–76.
Muhammad, S. D., Usman, M., Muhajid, M., & Lakhan, G. R. (2013). Nexus between energy consumption and economic growth: A case study of Pakistan. *World Applied Sciences Journal, 24*(6), 739–745.

Munir, S., & Khan, A. (2014). Impact of fossil fuel energy consumption on CO_2 emissions: Evidence from Pakistan (1980–2010). *The Pakistan Development Review*, *53*(4), 327–346.

Nawaz, S. M. N., & Alvi, S. (2018). Energy security for socio-economic and environmental sustainability in Pakistan. *Heliyon, 4*(10), e-00854.

Pakistan Economic Survey. (2016–2017). *Ministry of Finance, Government of Pakistan, Islamabad*. http://www.finance.gov.pk/survey/chapters_17/Pakistan_ES_2016_17_pdf.

Pakistan Economic Survey. (2017–2018). *Ministry of Finance, Government of Pakistan, Islamabad*. http://www.finance.gov.pk/survey/chapters_18/14-Energy.pdf.

Pakistan Energy Yearbook. (2018). *Ministry of energy (Petroleum Division) Hydrocarbon development institute of Pakistan*. https://hdip.com.pk/contents.php?cid=32.

Pesaran, M. H., Richard, J., & Shin, Y. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Economics, 16,* 289–326.

Phillips, P. C. B., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika, 75,* 335–346.

Raza, M. Y., Wasim, M., & Sarwar, M. S. (2019). Development of renewable energy technologies in rural areas of Pakistan. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 15,* 1–21.

Rehman, S. A. U., Cai, Y., Mirjat, N. H., Walasai, G. D., & Nafees, M. (2019). Energy–environment–economy nexus in Pakistan: Lessons from a PAK-TIMES model. *Energy Policy, 126,* 200–211.

Rivera-Batiz, L. A., & Romer, P. M. (1991). International trade with endogenous technological change. *European Economic Review, 35,* 971–1001.

Sadorsky, P. (2013). Do urbanization and industrialization affect energy intensity in developing countries? *Energy Economics, 37,* 52–59. https://doi.org/10.1016/j.eneco.2013.01.009.

Satti, S. L., Hassan, M. S., Mahmood, H., & Shahbaz, M. (2014). Coal consumption: An alternate energy resource to fuel economic growth in Pakistan. *Economic Modeling, 36,* 282–287.

Shahbaz, M., & Dube, S. (2012). Revisiting the relationship between coal consumption and economic growth: Cointegration and causality analysis in Pakistan. *Applied Economics International Development, 12*(1), 1–13.

Shahbaz, M., Tiwari, A. K., Jam, F. A., & Ozturk, I. (2014). Are fluctuations in coal consumption per capita temporary? Evidence from developed and developing economies. *Renewable and Sustainable Energy Reviews, 33,* 96–101.

Shahbaz, M., Zeshan, M., & Afza, T. (2012). Is energy consumption effective to spur economic growth in Pakistan? New evidence from bounds test to level relationships and Granger causality tests. *Economic Modelling, 29*(6), 2310–2319.

Shahbaz, M., et al. (2013). Natural gas consumption and economic growth in Pakistan. *Renewable and Sustainable Energy Reviews, 18,* 87–94.

Statistical Review of World Energy. (2018). https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf.

Vision, 2035. (2014). *Pakistan 2035, One Nation-one Vision. Planning Commission, Ministry of Planning, Development & Reforms. Government of Pakistan, Islamabad*. https://www.sdpi.org/publications/files/Pakistan%20Energy%202035FINAL%2020th%2December%202014.pdf.

Wenbo, G., & Yan, C. (2018). Assessing the efficiency of China's environmental regulation on carbon emissions based on Tapio decoupling models and GMM models. *Energy Reports, 4,* 713–723.

Wolde-Rufael, Y. (2010). Coal consumption and economic growth revisited. *Applied Energy, 87,* 160–167.

Xu, J., Zhou, M., & Li, H. (2018). The drag effect of coal consumption on economic growth in China during 1953–2013. *Resources, Conservation and Recycling, 129,* 326–332.

Yoo, S. H. (2006). Causal relationship between coal consumption and economic growth in Korea. *Applied Energy, 83*(11), 1181–1189.

Zahid, A. (2008). Energy–GDP relationship: A causal analysis for five countries of South Asia. *Applied Economics International Development, 1,* 167–180.

Zhang, B., Wang, B., & Wang, Z. (2017). Role of renewable energy and non-renewable energy consumption on EKC: Evidence from Pakistan. *Journal of Cleaner Production, 156,* 855–864.

Zhang, M., Bai, C., & Zhou, M. (2018). Decomposition analysis for assessing the progress in decoupling relationship between coal consumption and economic growth in China. *Resources, Conservation and Recycling, 129,* 454–462.

Zhao, C., & Luo, K. (2018). Household consumption of coal and related sulfur, arsenic, fluorine and mercury emissions in China. *Energy Policy, 112,* 221–232.