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RESEARCH ARTICLE

The path to achieving environmental sustainability in South Africa: the role of coal consumption, economic expansion, pollutant emission, and total natural resources rent

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Abstract
Statistics from the Intergovernmental Panel on Climate Change (IPCC) reveals that energy consumption remains the main root cause of anthropogenic greenhouse pollutant emissions because of economic expansion. Thus, the need to explore the determinants of environmental degradation in South Africa is pertinent for policymakers and stakeholders. The current study is conducted in a multivariate framework using an augmented carbon income function. The present study explores the theme under review with the inclusion of total natural resource rent as an additional variable to circumvent for omitted variable bias. To this end, annual time series data from 1970 to 2017 is employed for econometrics analysis. The study set off with investigation of stationarity properties with conventional unit root test in conjunction with Zivot-Andrews unit root test that accounts for single structural break. The Pesaran's bounds testing techniques traces long-run equilibrium relationship between energy (coal) consumption, pollutant emission, total natural resources rent, and economic expansion over the sampled period. Empirical test from the modified Wald test detect and validate feedback causality between energy (coal) consumption and economic expansion. This is instructive to energy stakeholders and policymakers that energy is key determinant of economic growth. Furthermore, total natural resources rent shows significant contribution to pollutant emissions in South Africa. Based on the empirical results, policy direction such as adoption of new technologies and cleaner energy sources were suggested rather than fossil fuel driven economy in South Africa.

Keywords Conservative energy consumption · Pollutant emission · Economic expansion · Carbon capturing and storage · South Africa

JEL classification C32 · C23 · Q5

Introduction

The usage of coal serves as an alternative source of energy use by many developed and developing economies to complement the traditional sources in other to help quench the increasing high demand for energy, which the tradition sources could not efficiently meet. Another reason for giving preference for coal consumption as an alternative source of energy is that it is cheaper and more readily available comparatively. For instance, in 2005, the total world energy derived from fossil fuel constitutes 34.3% from oil, coal 25.1%, and gas 20.9%, as asserted by world coal institute a coal facts outlook (Wolde-Rufael 2010).

In South Africa particularly, economic growth has witness an upward trajectory since the advent of democracy in 1994

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except for 2007 where the country was plunge into financial crises that emanated from a fall in global commodity price. The economy picks up again after the crises and remained almost stable until recently as asserted by Shahbaz et al. (2013a, b). On the other hand, the contribution of coal to energy generation in South Africa cannot be over emphasized. In reality, coal is one of the major economic resources that is contributing to the economic expansion (GDP) accordingly through its direct and/or indirect effect on critical sectors such as industry and investment. Characteristically, South Africa is the highest consumer of coal in the Sub-Saharan region and the continent of Africa. In fact, report from the energy council (WEC 2016) indicates that South Africa energy generation is coal-intensive as a result the country is the 6th biggest coal producer globally. For instance, in 2005, coal alone generates over 72% of the total basic energy supply in South Africa (Shafiee and Topal 2008). In the most recent time, power generated from coal source account for 95% of the total, and all the other sources account for only 5% in South Africa, World Bank development indicator (2008).

The growth trajectory of the South African (SA) economy on its energy sector predominantly driven by coal comes with it environmental pros and cons. On the other hand, CO_2 emission in SA is significant as it accounting for about 1% of the global total. This is empirically linked to the use of coal (Shahbaz et al. 2013a, b). Similarly, the US energy information administration (EIA 2010) reports that South Africa produces the highest carbon emission among the non-oil producing economies globally. According to EIA (2010), Nasr et al. (2015); Solarin et al. (2017) about 42% of the total emission produce in the continent of Africa is contributed by the South African economy, which is in excess of the total emission emanating from the Sub-Saharan region as a whole. This according to them is majorly linked to her coal sector operation. They added that in 2009, South Africa coal reservation accounts for 3.68% of global total. Coal is use to meet about 77% of the basic energy need in South Africa. This suggests that coal consumption is central to the economy of South Africa which demands more than the current attention from the research world to ascertain the empirical reality of the subject matter, especially for a single country study such as Ziramba (2009); Shahbaz et al. (2013a, b); Bekun et al. (2019a, b).

In contrast, however, only little research work has been carried out on the subject matter, most of which are panel studies Wolde-Rufael (2009) which may not properly account for the said nexus for a single country like South African. Shahbaz et al. (2013a, b) submits that coal usage and economic progress nexus are still subject to single country base debate in the case of South Africa. Finally, the inclusion of the natural resource rent became necessary because the economy is mainly dependent on the natural resources, majorly goal, iron ore, and platinum, which remain the biggest contributors to the economy as well as the main exports component. These reasons are the main driving forces behind this research work. Thus, this study is not just relevant but also timely as the study seeks to carry out a separate study on South Africa spanning from 1970 to 2017 to compliment the already existing body of knowledge. In conclusion, the recommendation from this study is expected to serve as a guide to the policymaker and the government of South Africa to formulate policies that will bring about the effective and efficient management and maximization of coal consumption in South Africa and her counterparts, coal-intensive economies.

The remainder of this study is structured as: Section 2 focuses on literature and empirical review. Section 3 presents data and empirical procedures while section 4 discusses/interprets empirical results. Finally, section 5 renders the concluding remarks and policy direction.

Brief literature and empirical review

The debate on the coal consumption-led growth nexus took another dimension in recent time due to the high demand for coal as alternative source of energy in many economies. Some study remain neutral as to whether or not coal consumption drive growth or otherwise, while some lent their supports to coal consumption as a driving force for economic progress, others hold the opposite view. Finally, some empirical studies show feedback causality. This study highlights four relevant hypotheses as supported by empirical findings. Firstly, the growth hypothesis argues that an increase in the growth process is the consequence of a progressive consumption of coal. Supporting this hypothesis are the works of authors such as Saint et al. (2019). Their study employed the dynamic ARDL bounds testing to cointegration and found that the study's series converged in the long-run. This study also revealed a unidirectional link running from coal consumption to economic expansion which implies that coal consumption is a driving force behind economic progress in South Africa. Similar work was carried out by Jin and Kim (2018) for panel data. Their panel study was carried out to investigate the relationship between coal usage and economic expansion for 30 OECD and 23 non-OECD countries using the fully modified OLS. The result reveals a long-run equilibrium between economic expansion and coal consumption only for the non-OECD countries. The result further proves that coal consumption and economic growth are negatively related for the non-OECD countries in the distance future. However, the growth hypothesis was proven for this developing economies sampled in this study. This is similar to the work of Ulucak and Bilgili (2018) and Chu et al. (2017) who found that energy consumption is a driver of economic growth. Bekun et al. (2019a) undertook a related study in the case of South Africa where the dynamic ARDL bounds test to cointegration by Pesaran et al. (2001) that was adopted in addition to Bayer and Hanck (2013) combined cointegration approach and

Table 1 Summary statistics

	$LNCO_2$	LNGDP	LNCOAL	LNTNR
Mean	5.682808	8.775402	4.126005	1.657303
Median	5.755400	8.761604	4.236959	1.639408
Maximum	6.107774	8.933624	4.541417	2.678582
Minimum	4.896834	8.615685	3.308790	0.650280
Std. Dev.	0.357685	0.094864	0.360874	0.455456
Skewness	− 0.728683	0.231633	− 0.928916	0.066297
Kurtosis	2.394468	2.049274	2.596518	2.765095
Jarque-Bera	4.981169	2.236988	7.228675	0.145523
Probability	0.082862	0.326772	0.026935	0.929823
Sum	272.7748	421.2193	198.0483	79.55055
Sum Sq. Dev.	6.013117	0.422964	6.120812	9.749682
Observations	48	48	48	48

Variables are in their natural logarithm form

Kripkganz and Schneider (2018). The result confirmed the existence of a long-run relationship between the variables understudied in South Africa. The result further proves that coal consumption is a key driver of economic expansion in South Africa. Coal consumption was also found to be a high emitter of carbon in South Africa. Bekun et al. (2019b) who submits that only energy causes economic advancement in South Africa. In another related study, Sarkodie and Adams (2018) found a unidirectional link running from energy consumption to economic advancement in South Africa, similar to the works of Akadiri et al. (2019), Wang et al. (2018). Apergis and Payne (2010) submit that energy conservation policy will slowdown growth process in an economy where coal is a driver of economic growth. Wolde-Rufael (2009) submits that the use of coal drives growth progress accordingly in India and Japan. Wolde-Rufael (2004) contends that coal consumption exerts causal effect on economic growth. Shui and Lam (2004) and Yuan et al. (2007) posit that only electricity usage exerts causal effect on GDP in China contradicting the work of Destek and Sarkodie (2019). While Li & Leung (2012) and Wolde-Rufael (2010) empirically found a direct link between the variables running only from coal usage. Ziramba (2009) contends that only coal consumption drives growth process accordingly. Ewing et al. (2007) opine that coal consumption is responsible in part for the increase in industrial productivity in the USA. This confirmed the work of Sari et al. (2008) where they found that coal consumption promotes industrial output appropriately. Similarly, Narayan and Smyth (2005) establish a one-way link between the series from their empirical findings. Shahbaz et al. (2013a, b) submits that only energy causes economic advancement in China, similar to the findings of Erol and Yu (1987); Soytas and Sari (2003); Thomas (2004); Bekun et al. (2019a, b). Under this hypothesis, any policy for energy conservation targeted at reduction of coal consumption is capable to slow down the process of economic growth. Secondly, the conservation hypothesis argued that economic growth is responsible for the increase demand for coal. The study of Jinke et al, (2008) submit that GDP causes the demand for coal usage without the later causing the former in China and Japan. According to Reynolds and Kolodziej (2008), economic growth is a promoter of coal usage in the former Soviet Union, similar to the study of Govindaraju and Tang (2013) for India. Yuan et al. (2008a, b) discovered a unidirectional effect running from GDP only. Yang (2000a) discovered a one-way causal effect running from economic growth to coal consumption. This is not different from the work of Fatai et al. (2004) in the case of Australia as well as the work of Jinke et al. (2008) and Wolde-Rufael (2010) in the case of China. The studies of Soytas and Sari (2003) and Jumbe (2004) confirmed the nexus under study for the Italian and Malawian economies. The work of Zhang and Xu (2012) lent support to the work of Soytas and Sari (2003) and Jumbe (2004) as stated above. Govindaraju and Tang (2013) conclude that economic growth is a driving force for CO_2 in China. Soytas and Sari (2003) discover economic growth to be a driving force behind energy consumption in Italy. In this case, an energy conservation oriented economy is safe from an inverse growth process. Thus, the conservation policies could possibly result to setting the economy on a path that is probably more technology-intensive and less coal-intensive as the economy keep expanding. Thirdly, the feedback hypothesis highlight the mutual dependent link that exist between the series as support by some group of studies such as the work of Wolde-Rufael (2010) who examined South African economy and discovers a mutual influence between the variables, consistence with the work of Wolde-Rufael (2010) for the case of USA. Similarly, Wolde-Rufael (2009) confirmed this hypothesis for the economies of South

Table 2 Correlation coefficient matrix analysis

t-statistic	–			
Probability	–			
No. of observations	48			
GDP	0.326418	1.000000		
t-statistic	2.342166	–		
Probability	0.0236	–		
No. of observations	48	48		
Coal	0.995199	0.254884	1.000000	
t-statistic	68.96394	1.787753	–	
Probability	0.0000	0.0804	–	
No. of observations	48	48	48	
TNR	0.224552	0.511012	0.226715	1.000000
t-statistic	1.562902	4.032062	1.578765	–
Probability	0.1249	0.0002	0.1212	–
No. of observations	48	48	48	48

Series are in their level form

Table 3 Unit root test (without break date)

Statistics (level)	$LNCO_2$	LNRGDP	LNCOAL	LNTNR
τ_T (ADF)	− 1.142	− 1.384	− 1.039	− 2.834
τ_μ (ADF)	− 3.159**	− 0.874	− 3.165**	− 2.955**
τ (ADF)	3.690	0.599	2.871	− 0.253
τ_T (PP)	− 1.075	− 1.073	− 0.943	− 2.774
τ_μ (PP)	− 3.321**	− 0.605	− 3.321**	− 2.927**
τ (PP)	3.186	0.854	2.551	− 0.098
Statistics (first difference)	$LNCO_2$	LNRGDP	LNCOAL	LNTNR
τ_T (ADF)	− 6.961***	− 4.355***	− 6.867***	− 8.139***
τ_μ (ADF)	− 6.001***	− 4.265***	− 5.934***	− 8.121***
τ (ADF)	− 4.895***	− 4.253***	− 5.185***	− 8.185***
τ_T (PP)	− 6.975***	− 4.301***	− 6.903***	− 8.139***
τ_μ (PP)	− 6.004***	− 4.258***	− 5.934***	− 8.143***
τ (PP)	− 4.951***	− 4.243***	− 5.205***	− 8.208***

ADF and PP unit root tests were performed where *, **, and *** denote rejection of the null hypothesis at the 1%, 5%, and 10% levels, respectively

Africa and USA. Yoo (2006) and Yang (2000a, b, c) found a mutual link between the series in Korea and Taiwan economies respectively. Yuan et al. (2008a, b) found feedback in the long-run. Yang (2000b) Lee and Chang (2005) present an empirical evidence of two way link between the series of interest, similar to the work of Yuan et al. (2008a, b) and Yoo (2006) in the case of the Korean economy. Others who found a two-way causal effect includes Belke et al. (2011) and Fuinhas and Marques (2011). Paul and Bhattacharya (2004) and Yuan et al. (2008a, b) in their separate studies found a mutual interaction between coal usage and economic advancement in India and Taiwan. The economic implication here is that any energy conservation policy is harmful to the economic progress just as a slowdown in economic activities could relatively drive low the consumption of coal. Fourth, the neutrality hypothesis submits that the impact of coal consumption on economic progress is minor or possibly not evidenced in reality. In this scenario, the growth process would not be affected regardless of a cut in coal usage through the energy conservation policy. For instance, Wolde-Rufael (2009) found that coal is not a promoter of growth for the economies China and South Korea. While a non-causal effect occurred in South Africa which confirmed the work of Yuan et al. (2008a, b) carried out for the Chinese economy. Fatai et al. (2004) found a non-causal effect between the series in New Zealand. The work of Jinke et al. (2008) proves that there is no causal link between coal usage and productivity for South Africa. Ziramba (2009) submit that there is absence of any link between the series in South Africa. Payne (2009) is of a view from his findings that the series exhibits a divergent link

Table 4 Zivot-Andrew non-stationarity test (with break date)

	Statistics (level)			Statistics (first difference)			
	ZA_I	ZA_T	ZA_B	ZA_I	ZA_T	ZA_B	Summary
LNCO2	− 3.384	− 2.843	− 3.998	− 7.476***	− 7.624** *	− 7.881**	I (1)
Period	1981	1983	1981	2003	2009	2003	
Lag	1	1	1	1	1	1	
LNRGDP	− 3.088	− 3.313	− 3.927	− 5.299**	− 4.551**	− 5.288**	I (1)
Period	1985	1993	1990	1994	2007	1994	
Lag	1	1	1	1	1	1	
LNCOAL	− 3.526	− 3.233	− 4.411	− 7.206***	− 6.919***	− 7.638***	I(1)
Period	1980	1985	1981	2003	1982	1983	
Lag	1	1	1	1	1	1	
LNTNR	− 3.507	− 3.075	− 3.378	− 9.223***	− 8.528***	− 9.139***	I(1)
Period	1987	1999	1986	2000	1985	2000	
Lag	1	1	1	1	1	1	

*, **, *** indicate 1%, 5% and 10% level respectively

Table 5 ARD results. Model: CO2 = f(GDP,COAL,TNR)

Variables	Coefficient	S.E	t-statistic	*P* value
Short-run				
RGDP	0.1994***	0.0632	3.156	0.0061
COAL	0.8031***	0.0319	25.1279	0.0000
TNR	0.0005	0.0056	0.0872	0.9316
ECT	− 0.5142***	0.0932	−5.5186	0.0000
Long-run				
RGDP	0.3843***	0.0607	6.3247	0.0000
COAL	0.9872***	0.0189	52.2759	0.0000
TNR	− 0.0473**	0.0175	−2.7125	0.0154
Diagnostic tests				
Tests	F-statistic	Probability value		
χ^2 SERIAL	2.456	0.122	F(2, 14)	
χ^2 WHITE	1.122	0.414	F(25, 16)	
χ^2 RAMSEY	1.459	0.245	F(1, 15)	

*, **, *** indicate 1%, 5%, and 10% level, respectively

between them confirming the study of Stern (1993) who found non-directional link between series for the US economy. Other previous empirical studies such as Yang (2000a, b, c), Sari and Soytas (2004), and Lee and Chang (2005) arrived at their separate positions as regards nexus under investigation.

Methodological steps and data source

This study explores the interaction between economic growth, coal consumption, pollutant emissions, and total natural resource rent. To achieve this object, data from the World Bank database with the exception of coal consumption from the British petroleum (BP) database ranging from 1970 to 2017 was retrieved. The variables under investigation includes real GDP as proxy for economic growth (constant 2010, US$), total natural resource rent (%GDP) in US dollars, coal consumption (Mtoe), and CO_2 in (Kt) emissions. This study converted the variables of interest to a form conventional known as natural log in an attempt to achieve the growth effect.

Table 6 ARDL bounds test

Test statistic	Value	K
F-stat	4.8728	3
Critical value bounds		
Significance	I(0) Bounds	I(1) Bounds
10%	2.56	3.43
5%	3.07	4.02
1%	4.27	5.41

Source: Author computation, 2018

Stationary tests

The non-stationarity form of time series data make it necessary to perform a stationarity test to establish the level of the integration of the variables of interest Gujarati (2009). One of the major essences of the stationarity test is to avoid spurious regression which is capable to mislead the outcome of the empirical investigation. To achieve this, the ADF and PP proposed by Dickey and Fuller (1981) and Phillip and Perron (1988) as generally accepted were adopted by this study. The generalized formula is as follow (Eq. 1):

$$\Delta Y_t = \beta_1 + \beta_2 + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

where Gaussians white noise that is assumed to have a mean value of zero is represented byε_t, and possible autocorrelation represent series to be regressed on the time t.

ARDL bounds testing

It is a common knowledge that macroeconomic variables are subjected to cointegration test to determine whether or not they converged in the long-run due to their drift nature. Thus, this study adopted the ARDL bounds test as developed by Pesaran et al. (2001) to test for cointegration. The choice of this method follow it wide acceptability as been superior, advantageous, and flexible than the traditional methods because it can be use even when all variables are in mutual order of integration i.e., either I(1) or I(0), or otherwise. The method is majorly used to determine the long-run equilibrium state of the variables in the functional model. The equation is stated as follow (Eq. 2):

$$\Delta Z = \varepsilon_0 + \varepsilon_1 t + \lambda_1 \delta_{t-1} + \sum_{i-1}^{k} \phi_1 \nu_{it-1} + \sum_{j-1}^{n} \varphi_j \Delta Z_{t-j} + \sum_{i-1}^{k} \sum_{j-1}^{n} \omega_{ij} \Delta V_{it-j} + \Upsilon D_t + \mu_t \quad (2)$$

$$H_0 : \varphi_1 = \varphi_2 = \ldots. = \varphi_{n+2} = 0$$
$$H_1 : \varphi_1 \neq \varphi_2 \neq \ldots. \neq \varphi_{n+2} \neq 0$$

where the rejection of H_0 indicates a proof that the series converged in the long-run to correct any initial short-run disturbance.

Preliminary analysis

This section presents the preliminary analysis of this study, starting with the stationarity tests through the adoption of the widely accepted ADF, PP, and the Zivot-Andrew unit root tests to determine the stationarity of the variables of interest. This study went further to plot the graph of the variables to ascertain the trends of the variables. Other tests includes

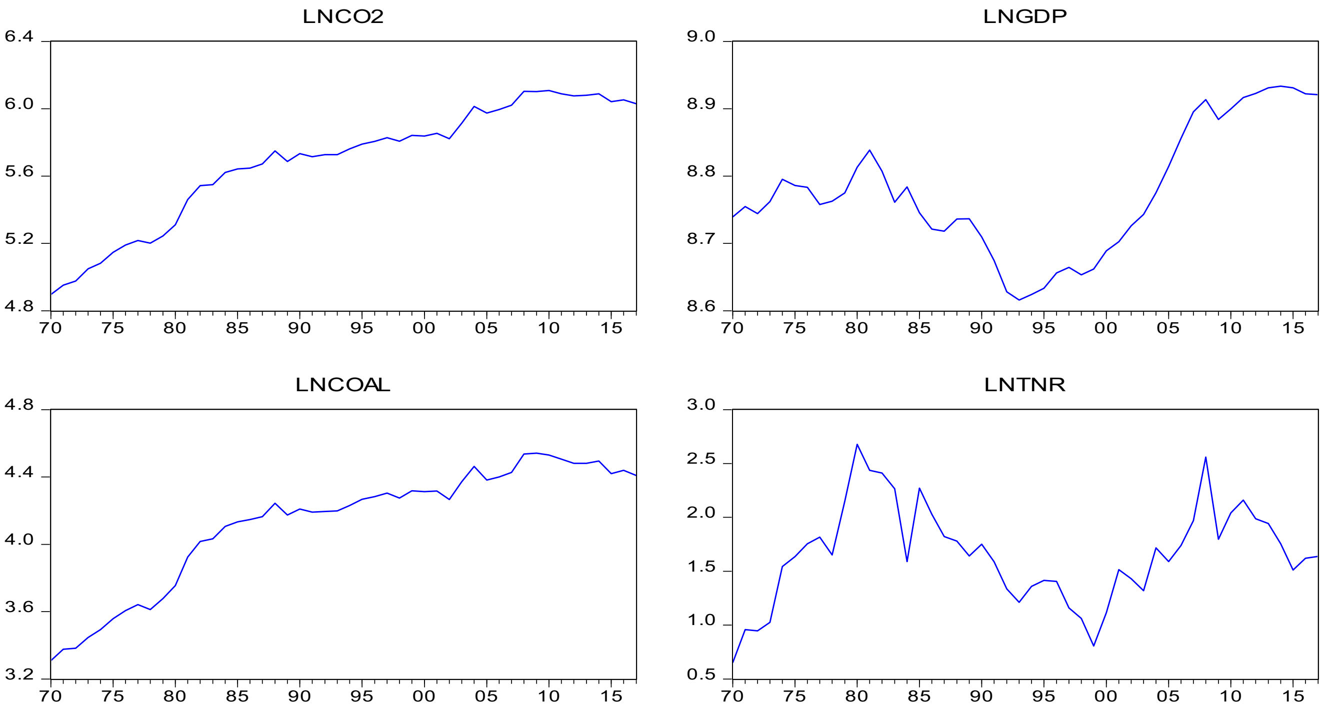

Fig. 1 Visual plots of series under investigation

summary statistical test and correlation coefficient matrix which are presented as follow.

The empirical result from Table 1 above indicates that GDP has a larger average as against the other variables. The standard deviation of the series indicates that the dispersion of the series from their means is averagely evidenced. The Jargue-Bera result also revealed that the series are normally distributed but for RGDP and TRN. Also, the series demonstrate an overall mutual significance and positive link as indicated from the Pearson coefficient correlation except for a positive but weak interaction between TRN and coal and between TRN and CO2 (see Table 2).

The result of the tests from the widely known ADF and PP as presented in Table 3 shows that all series except for RGDP are stationary at level given 5% degree of significance. The results turn out to be different at first difference where the series prove to be stationary given a 1% significance level. Result from the Zivot-Andrew unit root test shows that none of the series was stationary at level, instead the stationarity of the series was establish at first difference, with CO_2, COAL, and TRN been stationary at 1% level of significance while GDP became stationary at 5% level of significance (Table 4).

Empirical results and discussions

This section presents the empirical findings from the study. Considering the fact that the unit root tests indicates a mixed order of integration, the study deemed it fit to employ the ARDL bounds test which is most suitable for testing of long-run equilibrium, and the result is presented in Table 5

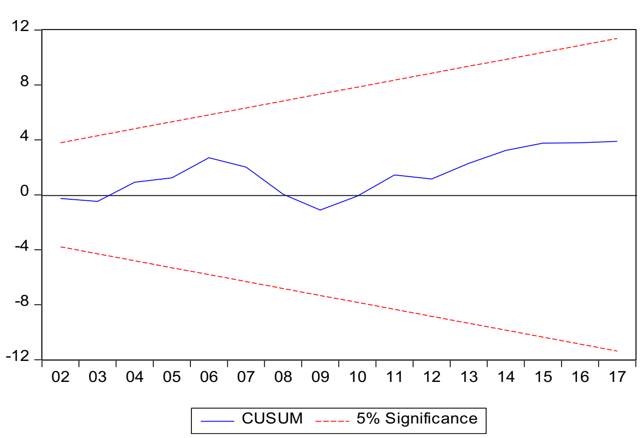

Fig. 2 Plot of CUSUM showing stability

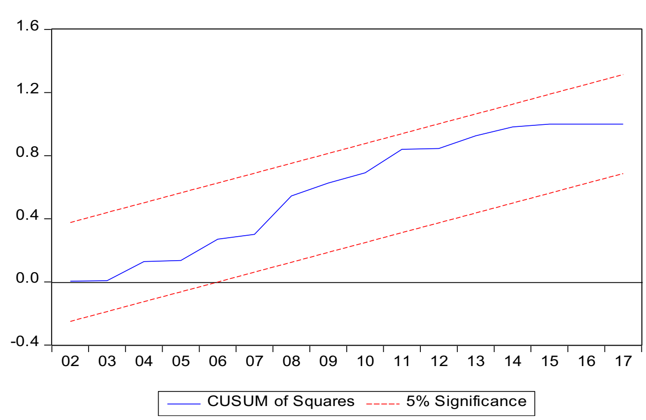

Fig. 3 Plot of CUSUMSQ, which indicates stability

Table 7 Granger block exogeneity results

Excluded	Chi-squared	df	Probability
Dependent variable: LNCO2			
LNGDP	5.4031	1	0.0201**
LNCOAL	4.6338	1	0.0316**
LNTNR	9.4522	1	0.0021**
All	9.5279	3	0.0230**
Dependent variable: LNGDP			
LNCO2	114,187	1	0.0007***
LNCOAL	10.9919	1	0.0009***
LNTNR	0.0729	1	0.7872
All	18.9660	3	0.0003
Dependent variable: LNCOAL			
LNCO2	5.5883	1	0.0181**
LNGDP	7.4424	1	0.0064***
LNTNR	13.4866	1	0.0002***
All	13.5073	3	0.0037**
Dependent variable: LNTNR			
LNCO2	1.3245	1	0.2498
LNGDP	3.1100	1	0.9986**
LNCOAL	1.5437	1	0.2141
All	8.1761	3	0.0425**

Significance at *** 0.01 and ** 0.05

below. The findings indicate that GDP exerts positive significant impact on CO_2. That is about 19% change in CO_2 is brought about by every 1% change experience in its growth process. The implication is that the South African economic growth path is pollutant emission driven which is insightful as the nation ranks high among pollutant counties of the world. This means the country is still at the scale stage of her growth trajectory progress (Agboola and Bekun 2019; Sinha and Shahbaz 2018). The outcome also resonates the environmental Kuznets concept, where there is a link between income per capital and economic growth. This is a call for more pragmatic action step on policymakers and stakeholder in South Africa to disentangle economic growth from pollutant emission in her energy policy mix. Similarly, coal consumption exhibits positive and significant influence on economic growth with a very high magnitude in both short- and long-run. However, coal consumption alone constitutes about 80% of the changes that occurs in the CO_2. On the contrary, TRN exhibit a positive but a very weak impact on CO_2 as it is responsible for only 0.05% change in CO_2. While a significant inverse relationship in the long-run is observed as reported in Table 5, which is desirable and laudable as the nation join global quest to mitigate against pollutant emissions via natural resources exploration and extraction like coal which serves as main South African energy source (Beg et al. 2002; Bekun et al. 2019a). The result of the bounds testing to cointegration as presented in Table 5 revealed that at 10 and 5% we reject the null hypothesis, which means that the series converge in the long-run equilibrium path. The model of this study was diagnose and the result presented in Table 6 showing that the model is normally distributed, free from model specification error as well as heteroscedasticity problem. Thus, the fitted model is suitable and parsimonious for policy direction, while the CUSUM and CUSUMSQ test as presented in Figs. 1 and 2 and 3 is use to determine the stability of the fitted model. The result indicates a stability of the coefficients for the time frame since the plot of the blue line fall within the 5% critical lines as supported by Emir and Bekun (2019) and Okunola (2016).

Finally, the present study employ the TY Granger causality test as presented in Table 7 to detect the causality direction flow among the variable under consideration. The result shows a bi-directional link between coal consumption and economic growth confirming the coal consumption-economic growth nexus for South Africa. Similarly, this study confirms the EKC hypothesis as there is a feedback interaction between CO_2 and the income (GDP). While between coal consumption and CO_2, there exists a mutual relationship as prove by the findings. These findings have far-reaching implications. For instance, the feedback causality relationship between energy (coal) consumption and economic expansion implies that the South African government administrators cannot embark on energy cut down strategies or policies, as this will have detrimental effect on economic growth. Thus, the need for policy mix, which focuses on decoupling economic growth from pollutant emission, should be the central focus of the government. Furthermore, the total natural resources rent induce pollutant emission is worthy of caution for stakeholder as we see a one-way from the causality results in Table 7.

Conclusion

Sustainable economic growth and clean energy consumption is a key path for most if not all government administrator in this contemporary era. This country specific study investigates the long-run relationship and causality relationship between the energy (coal) consumption, total natural resources rent, pollutant emission, and economic expansion. These variables were confirmed by the dynamic ARDL bound test to have long-run equilibrium relationship over the sampled period for the case of South Africa. The revelations from the TY Granger causality test show that coal consumption and economic growth drive each other accordingly confirming the coal consumption-economic growth nexus for South Africa which is self-educative to the policy makers. Alternatively, this implies that coal consumption is very healthy to the economy of South Africa. Thus, informing the policymakers that any attempt to formulate conservation policy targeted at the reduction of coal consumption will drastically slow down economic progress. Findings from this study also confirm the EKC hypothesis for the South African economy as indicated by the feedback link connecting CO_2 and GDP (income). These outcome are suggestive to the authority of South African economy that caution is needed in her energy mix in terms of selection on her energy policy measures to adopt for the economy. Thus, this study recommends a gradual drift from coal-intensive energy which is environmental unfriendly energy which drives a significant part of the SA economy to move to cleaner energy sources such as renewables like wind energy, solar, and photovoltaic energy which are reputed to be cleaner and more eco-system friendly the environment at large (Baloch 2019; Samu and Bekun 2019). The need to reinforce commitment to local and international environment treaties are encouraged for the South African economy in an attempt to set the economy on the path of economic growth. The reason is that achieving economic expansion will in turn promote the well-being of the South Africans as economic growth means improvement in the standard of living. Therefore, this study strongly warned that the quest for economic expansion should be careful manage in such a way that will avoid serious pollution emissions otherwise in future the negative consequences from economic prosperity will turn out to pose serious environmental danger through degradation which by extension could undue its developmental path (Solarin and Shahbaz 2013;Shahnaz and Sinha 2019). The bidirectional causal relationship between CO_2 and coal consumption should also draw the attention of the policymaker in South Africa due to the global warning against the danger of incessant environmental degradation. A dual or balanced policy must be put in place to ensure that emission from coal consumption is kept within the level that can be manage without posing serious harm to the economy.

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