



New insight into the causal linkage between economic expansion, FDI, coal consumption, pollutant emissions and urbanization in South Africa

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Abstract

This study examines the relationship between foreign direct investment inflows and economic growth in a carbon function, by incorporating the role of urbanization, and coal consumption as additional variables to avoid omitted variable bias. The different order of integration from the unit root test suggested the adoption of a dynamic autoregressive distributed lag bounds testing procedure. The results confirmed the existence of a long-run equilibrium relationship between the outlined series within the period under investigation, with a high speed of convergence. The ARDL equilibrium relationship shows that coal consumption is the largest emitter of carbon dioxide emissions in both short- (0.77%) and long-run (0.86%). Economic growth was found to escalate CO₂ emission by approximately 0.27% (in the short-run) and 0.19% (in the long-run). The Granger causality test indicates a non-causal effect between FDI inflow and economic expansion in South Africa, which implies that FDI is not a driver of economic advancement. The empirical study shows a bidirectional causal effect between urbanization and foreign direct investment. This suggests that urban development stimulates foreign direct investment in South Africa. The findings reveal a one-way link from GDP to coal consumption, suggesting economic prosperity promotes coal consumption. The study underscores that economic development and the attraction of more economic investments is in part dependent on the conservative policy, development of urban centers through infrastructural improvement, and establishing industrial zones.

Keywords South Africa · Coal consumption · CO₂ emissions · Climate change · Urbanization

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Introduction

Foreign direct investment (FDI hereafter) is seen by some scholars as a panacea for economic growth through its spill-over effect especially to developing economies. However, a consensus is yet to be established as to whether the impact of FDI inflow is gainful to the economic progress of the host countries. Some studies (Flora and Agrawal 2014; Kalai and Zghidi 2019) identify FDI inflow as a driving force for economic advancement. These studies label FDI inflow as a promoter of productivity, research and development, civilization, and improvement of skill and technical knowhow.

In contrast, some studies believe that FDI inflow is anti-economic progress, these include Joshua (2019). The study found a non-causal effect between economic expansion and FDI inflow in Nigeria. Similar to Bezuidenhout (2009) who reveals FDI as rather harmful to the economic progress of the host country, thus, FDI inflow is an engine of retardation to the host economy.

The linkage between coal consumption and economic expansion remains inconclusive. Some empirical findings from previous studies such as Joshua and Bekun (2020) adopted the dynamic ARDL approach and found that consumption promotes economic expansion both in the short- and long-run in South Africa, which is consistent with the work of Joshua et al. (2020). Other related studies supporting this claim include Bekun et al. 2019a, b; Apergis and Payne 2010. Other scholars believe that the nexus works the opposite way (see Govindaraju and Tang 2013; Zhang and Xu 2012; Jinke et al. 2008). These studies submit that coal consumption exhibits negative impact on economic expansion, thus, coal usage is an anti-growth agent. Other studies reveal that coal consumption and economic advancement exhibit a mutual benefit (see Paul and Bhattacharya 2004). A study particularly found a mutual interaction between the variables of interest (Paul and Bhattacharya 2004). On a related note, the outcome of other studies remains neutral regarding the impact of coal consumption on economic advancement (Ziramba 2009; Jinke et al. 2008; Lee and Chang 2005; Sari and Soytas 2004; Yang 2000). These studies maintain that the positive impact of FDI inflow on economic advancement as posited by some quotas is a mere presumption and not a reality.

South Africa is one of the very few largest and fastest emerging economies in Africa and globally. Its economy demonstrates peculiar characteristics different from other emerging economies in Africa. These distinctive features include an economy that is the largest emitter of CO₂ emissions in Africa (~45% of the continental total) and 7th in the world (Enerdata 2019). In addition, the share of energy generated from coal is about 77% of the total energy generation capacity and remains the largest consumer of coal in Africa (EIA 2010; Enerdata 2019). South Africa is the largest producer of natural resources such as gold, iron ore, and platinum (World Bank 2018). However, the country has witnessed turbulence in its quest to achieve both economic growth and FDI inflow. Despite this instability, the economy remains one of the leading economies in Africa especially after the takeoff of democracy in the country in 1994. For instance, in 2001 and 2002, the South African domestic currency weakened against the US dollar by 37%. This resulted in capital flight as investors discontinued their investment for fear of losing capital. Consequently, the rate of growth of GDP dropped significantly in the preceding year from 3 to 1.9% between 2002 and 2003. In 2005, GDP stood at \$6729.827 billion in absolute values. This rose to \$7432.117 billion in 2008 with a further increase in 2013 to 7563.993. In 2017, the GDP growth rate was estimated to be 0.7%, while unemployment accounted for 27% of the workforce. On the other hand, South Africa stands as a leader of FDI inflows to the Southern region and the second largest in Africa after Nigeria (UNCTAD 2012 \$ 2018). The report further indicates that South Africa received the second largest proportion of the FDI inflows to the

continent in 2011, accounting for about 13.6% share of the total. In 2013, South Africa received FDI inflows of about \$8300.1 million, followed by Mozambique which received \$6175.1 million. In 2017, the FDI inflows to South Africa stood at \$2.0 billion (UNCTAD 2018). In 2018, the FDI inflows to the southern region experienced an increase by 13% to \$32 billion out of which South Africa received the largest share of about \$5.3 billion, a sharp increase compared to 2017. It is estimated that about 87% of the total FDI inflows to South Africa come from the UK, whereas the rest of the world account for the remaining percentage (UNCTAD 2013).

These distinctive characteristics informed this study with the intention of adopting the TY Granger causality test using one functional model to achieve the following objectives: first, carry out a country-specific study on the FDI-led growth hypothesis because of no consensus in the empirical literature (Guimaraes et al. 2000; Fedderke and Romm 2006; Shahbaz et al. 2013; Sunde 2017; Khobai et al. 2017), especially for South Africa. Second, Nielsen et al. (2017) argued that industrialization, infrastructure improvement, and the seat of power (government) that characterizes the urban center could serve as a catalyst for attracting FDI inflows. The study opines that urban conglomeration with improved infrastructures is an agent for attracting FDI inflow into the host country, that is, urban centers are attractive sights for the inflow of new investors into the host country. This study seeks to investigate this claim by incorporating urbanization, coal usage, and CO₂ emissions in the FDI-growth hypothesis as control variables. Finally, this study examines the growth hypothesis which posits that coal consumption is a key driver of economic expansion. Thus, this study is well articulated and will serve as a pioneer work in future research, especially in the case of South Africa.

Literature review

The contention of the dynamic of FDI and its impact on economic expansion are yet to receive an empirical conclusion. While some quotas lend their support to the alleged positive impact of FDI inflow on economic progress, others reject it in totality. Joshua et al. (2020) examined the interaction between FDI inflows and economic expansion in South Africa using the dynamic ARDL approach. The findings revealed that FDI inflow exerts a positive impact on economic expansion both in the short- and long-run, which is not different from Shahbaz et al. (2019a, b). The study revealed that FDI promotes economic growth through its positive spillover effect on the quality of the environment consistent with the work of Balcilar et al. (2019). Shahbaz et al. (2019a, b) carried out similar work on the relationship between FDI inflows, education, and transportation infrastructure in the French economy using ARDL approach. The results

revealed cointegration between the series of interest. Further revelation showed that the relationship between FDI inflows and economic expansion is bidirectional. Shahbaz and Rahman (2012) examined the relationship between financial developments, import, and FDI inflows in Pakistan by adopting an ARDL bounds approach. The findings confirmed cointegration between the series, and that FDI exerts a positive and significant impact on economic expansion. In addition, a bidirectional relationship between FDI inflows and economic expansion was confirmed. According to Gungor and Katircioglu (2010), FDI drives economic growth positively in the case of Turkey. This is similar to the work of Gungor and Ringim (2017) for the case of Nigeria. Other extant literature (Sunde 2017; Tshepo 2014; Abbes et al. 2015; Sarkodie and Strezov 2019; Nistor 2014; Almfraji and Almsafir 2014; Omri and Kahoulib 2013) subscribes to the FDI-economic growth nexus. The spillover effect of FDI inflow is argued to drive economic progress faster than domestic investment (Borensztein et al. 1998), whereas others (Nair-Reichert and Weinhold 2001) argue that FDI could influence future growth in an open economy more than a closed economy. The impact of FDI inflows on economic progress though positive but was insignificant in the case of Nigeria (Ayanwale 2007); however, FDI inflows to India exerts a transitory effect on the service sector output (Chakraborty and Nunnenkamp 2008). Azman-Saini et al. (2010) submit that the impact of FDI inflow on economic advancement is not in view without attaining the minimum financial market development. Wang (2009) reveals that FDI inflow in the manufacturing industry promotes economic growth positive in a significant way for 12 Asian economies understudied, confirming the work of Yao (2006) in the case of China. Omri et al. (2014) find a two-way interaction between FDI inflow and economic growth for three regions studied, but the impact of FDI inflow could only be triggered by a strong financial improvement of the host country (Hermes and Lensink 2003). Fedderke and Romm (2006) confirm the complementary role of FDI inflow in the long-run in South Africa. On the contrary, other studies argued that FDI influences economic expansion negatively. Other studies with opposing view include Abdouli and Hammami 2017. The study examined the relationship between FDI inflows and economic expansion in the MENA countries and found a negative impact of FDI on economic progress in Egypt and Lebanon. The study of Adams (2009) revealed only a short-run negative effect of FDI on domestic investment which by implication hampers economic growth. Other studies remain neutral as to whether or not FDI inflow drives economic growth. Fedderke and Romm (2006) asserted that FDI causes capital flight in the short-run. Belloumi (2014) showed that FDI inflows do not significantly influence economic progress in Tunisia. Alfaro et al. (2004) asserted that the influence of FDI inflow on economic expansion without complementary role from other factors like the improved financial market is

uncertain. Joshua (2019) examined the relationship between FDI inflows, government expenditure, and economic expansion in Nigeria using the dynamic ARDL. The result revealed that FDI inflows do not drive economic prosperity. Similarly, (Flora and Agrawal 2014; Pandya and Sisombat 2017; Mehic et al. 2013; Goh et al. 2017 submitted that on the overall, there is no evidence of the positive impact of FDI in the long-run for the Asian economies, confirming the work of Mah (2010) and Khobai et al. (2017). Bezuidenhout (2009) proved that the perceived impact of FDI on economic growth is a fallacy for the southern Africa region.

The linkage between coal consumption and economic expansion remains inconclusive. Some empirical findings from previous studies such as Joshua and Bekun (2020) examined the relationship between coal consumption and economic expansion in South Africa using the dynamic ARDL. The findings revealed that coal consumption is a promoter of economic progress both in the short- and long-run, as well as an emitter of carbon emissions. This is similar to the work of Joshua et al. (2020), which examined the relationship between coal consumption, FDI inflows, economic expansion, and industrialization in South Africa. The findings showed a co-movement between the series in the long term, and that coal consumption is a key factor in promoting economic growth in both terms and that the variables co-move in the distance time. Bekun et al. (2019a, b) in separate studies found that coal consumption exerts a positive and significant impact on economic acceleration in South Africa both in the short- and long-run. The study further revealed a cointegration between the series within the period under review. This is similar to Balsalobre-Lorente et al. (2018), who examined the relationship between carbon emissions and economic expansion, and renewable electricity and natural resources in five EU countries. The findings revealed that renewable electricity, natural resources, and energy innovation promotes the quality of the eco-system. Alvarez-Herranz et al. (2017) examined the relationship between energy innovation, renewable energy, and carbon emission in 17 OECD economies. The findings revealed that energy innovation and renewable energy demonstrate a positive impact on economic expansion. Further revelation showed that energy innovation and renewable energy mitigate carbon emissions. The study of Alola and Alola (2019) found a cointegration between the series in South Africa. Shahbaz et al. (2019a, b) examined a similar relationship in the MENA economy and found an inverted shape link between economic expansion and carbon emissions. Saidi et al. (2018) examined the empirical link between transport energy consumption transport infrastructure and economic advancement in the MENA economies. The study found that transport energy usage exerts a positive impact on the economic growth of N-GCC and MATE part of the MENA, while transport infrastructure influences economic advancement of the MENA region. Adedoyin et al. (2019)

found a negative impact of coal rent on carbon emission in the BRICS economies. Others related studies (Apergis and Payne 2010; Ziramba 2009; Yuan et al. 2007; Shiu and Lam 2004) validated the coal consumption-led economic expansion nexus, whereas others believe that the nexus works the opposite way (Govindaraju and Tang 2013; Zhang and Xu 2012; Jinke et al. 2008; Reynolds and Kolodziej 2008; Soytaş and Sari 2003). Other studies revealed that coal consumption and economic advancement exhibit a mutual benefit (Paul and Bhattacharya 2004). On the concluding note, the outcome of several studies remains neutral regarding the impact of coal consumption on economic advancement (Ziramba 2009; Jinke et al. 2008; Lee and Chang 2005; Sari and Soytaş 2004; Yang 2000). These studies submit that the impact of coal consumption on economic expansion is a mere presumption which is far from reality.

Theoretical framework

This study is developed based on modernization and dependency theories. The modernization theory argues that FDI is an advantage to the host country especially the emerging economies because of its spillover effect in the form of, *inter alia*, technological advancement, and human capital development (Li and Liu 2005; Kumar and Pradhan 2002; Borensztein et al. 1998). The school of thought believes in economic openness which facilitates the inflows of FDI; hence, FDI is a key player in the economic expansion of the host country, especially the developing economies. They conclude that though FDI inflows may not be totally free from negative impact, its benefits outweighed the costs. In contrast, FDI is labeled by the dependency theory as an engine for capital flight (see Adams 2009; Clark and Chan 1996). The propagators of dependency theory argue that FDI is capable to undo the course of development through its crowding out effect, especially on the domestic investment. Thus, profits of the foreign firm are sent back to the head office in their home country, which facilitates the capital transfer from the host country. In a related development, four hypotheses have been advanced as a premise to explain the coal consumption-led growth nexus. First, the growth hypothesis asserts that economic progress is driven by coal consumption as supported by Adedoyin et al. (2020), in the BRICS economies. The study shows that coal rent demonstrates a significant negative impact on carbon emission. Other studies (see Bekun et al. 2019a, b) adopted the ARDL bound approach for South Africa and found a cointegration between the series. Further revelation showed that coal consumption is a key driver of economic expansion both in the short- and long-run, confirming that coal usage is an emitter of carbon emission. Apergis and Payne (2010), Ziramba (2009), Yuan et al. (2007), and

Shiu and Lam (2004) also lent their support to this assertion. Conservative hypothesis, on the other hand, posits that demand for coal is a derivative of economic growth (see Govindaraju and Tang 2013; Zhang and Xu 2012; Jinke et al. 2008; Reynolds and Kolodziej 2008; Soytaş and Sari 2003). Third, the feedback hypothesis is of the view that the interaction between coal consumption and economic development is a mutual relationship (see Paul and Bhattacharya 2004). The neutrality hypothesis asserts that the impact of coal consumption on economic development is a fallacy (see Ziramba 2009; Jinke et al. 2008; Lee and Chang 2005; Sari and Soytaş 2004; Yang 2000). Thus, from a policy perspective, hypotheses one and four support the conservation policy which encourages a reduction in coal consumption, whereas hypotheses three and two assert that conservation policy is harmful to economic growth.

Materials and method

To investigate the causal relationship between the series, the study used time series data from the World Bank database ranging from 1970 to 2017. The series includes real GDP as a proxy for economic expansion, FDI net inflow (% of GDP), urbanization (URB) represent the urban population as % of the total, and coal consumption which represents the value of coal in tons, and carbon emissions (CO₂). All series were converted to their log form to ascertain the growth rates of the series. The econometric procedure of this study consists of first, the unit root test for which the order of integration is determined in others to avoid estimation of a regression line that is spurious. Second, the estimation of cointegration to determine if a disturbance in the short-run is corrected in the long-run using ARDL bounds testing procedure. Finally, we use the dynamic T-Y Granger causality test to determine the causal interaction between the variables of interest. For brevity, the bounds test to cointegration is presented briefly after the model specification.

Model specification

The relationship establishes that carbon emission is a function of economic expansion (GDP), foreign direct investment (FDI) inflows, coal consumption, and industrialization. Thus, the functional form of the model is expressed as:

$$CO_2 = f(GDP, FDI, COAL, URB) \quad (1)$$

$$\begin{aligned} LnCO_2 = & \beta_0 + \beta_1 LnGDP + \beta_2 LnFDI + \beta_3 LnCOAL \\ & + \beta_4 LnURB + \mu_t \end{aligned} \quad (2)$$

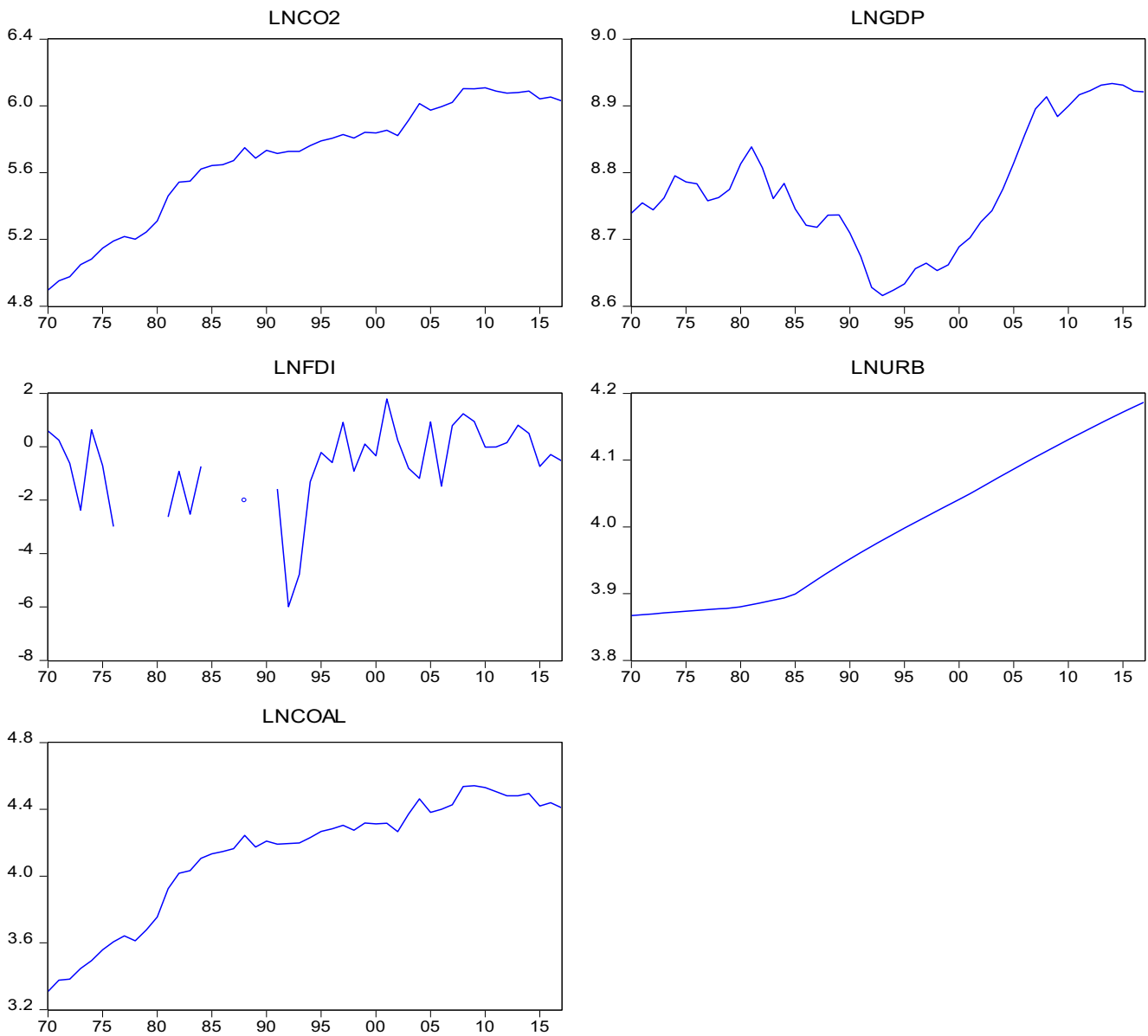


Fig. 1 Visual graph of the variables

where, β_0 is the model intercept, while $\beta_1, \beta_2, \beta_3,$ and β_4 connote the coefficient of RGDP, FDI, coal consumption, and industrialization.

ARDL bounds testing to cointegration

This study adopts the ARDL bound testing to cointegration developed by Pesaran et al. (2001) due to its dynamic nature. The ARDL procedure remains indifferent irrespective of the order of integration of the series under investigation. This implies that either the order of integration is I(1), I(0), or a mixture of both; the adoption of ARDL still remains valid for the purpose of the analysis. Thus, the formula is presented as:

$$\Delta Z = \mu_0 + \mu_1 t + \lambda_1 \delta_{t-1} + \sum_{i=1}^k \delta_1 v_{it-1} + \sum_{j=1}^n \varphi_j \Delta Z_{t-j} + \sum_{i=1}^k \sum_{j=1}^n \phi_{ij} \Delta V_{it-j} + \gamma D_t + \mu_t \tag{3}$$

where v_t is the estimate vector and D accounts for an exogenous variable which is the structural break within the study scope. The empirical hypothesis of the bound using f-statistic is stated below:

$$H_0 : \lambda_1 = \lambda_2 = \dots = \lambda_{K+2} = 0$$

$$H_1 : \lambda_1 \neq \lambda_2 \neq \dots \neq \lambda_{K+2} \neq 0$$

Table 1 Summary statistics

	LNCO2	LNNGDP	LNFDI	LNURB	LNCOAL
Mean	5.728704	8.781534	−0.676924	4.016755	4.167526
Median	5.821883	8.775257	−0.526894	4.024101	4.282794
Maximum	6.107774	8.933624	1.788230	4.187379	4.541417
Minimum	4.896834	8.615685	−5.993135	3.867214	3.308790
Std. dev.	0.368005	0.103445	1.585520	0.108153	0.370087
Skewness	−1.024367	0.057322	−1.364664	−0.055998	−1.205243
Kurtosis	2.846857	1.755786	5.297031	1.644816	3.122840
Jarque-Bera	6.858735	2.536968	20.67908	3.004735	9.466494
Probability	0.032407	0.281258	0.000032	0.222603	0.008798
Sum	223.4195	342.4798	−26.40005	156.6534	162.5335
Sum sq. dev.	5.146245	0.406631	95.52715	0.444486	5.204650
Observations	39	39	39	39	39

Natural logarithm of variables are presented

Thus, the rejection of H_0 indicates evidence of long-run convergence between the series and vice versa.

Preliminary

The preliminary analysis begins with a graphical technique to show the trend of the series as presented in Fig. 1. This is closely followed by the summary statistics (Table 1) which

Table 2 Pairwise correlation matrix analysis

Observations	CO2	GDP	FDI	URB	Coal
CO2	1.000000				
<i>t</i> statistic	–				
Probability	–				
No. of obs.	48				
GDP	0.456030	1.000000			
<i>t</i> statistic	3.475360	–			
Probability	0.0011	–			
No. of obs.	48	48			
FDI	0.364679	0.228995	1.000000		
<i>t</i> statistic	2.656305	1.595514	–		
Probability	0.0108	0.1174	–		
No. of obs.	48	48	48		
URB	0.932540	0.578416	0.425519	1.000000	
<i>t</i> statistic	17.51691	4.809126	3.189141	–	
Probability	0.0000	0.0000	0.0026	–	
No. of obs.	48	48	48	48	
Coal	0.992918	0.368745	0.348250	0.889777	1.000000
<i>t</i> statistic	56.68603	2.690554	2.519677	13.22265	–
Probability	0.0000	0.0099	0.0153	0.0000	–
No. of obs.	48	48	48	48	48

Series are in their level form

show that GDP relatively exhibits the highest average. The probability of the Jarque-Bera test for three of five variables is significant, concluding that the variables are not normally distributed. The Pearson coefficient correlation matrix (see Table 2) on the other hand reveals that the outcome is in line with the empirical intuitions. For instance, there is a very strong interaction between CO₂ and coal consumption, which is not far from the empirical assertion that the latter is a major emitter of the former. Another significant relationship exists between urbanization and GDP indicating that the former is a driver of the latter and vice versa. The results further show that coal consumption strongly correlates with GDP which confirms the growth hypothesis. Thus, on the overall, the result shows a strong positive link between the series. The stationarity test from Augmented Dickey–Fuller (ADF) test presented in Table 3 shows that all variables are stationary at level—at different statistical significance except for GDP. The same is applicable to the Phillips–Perron (PP) test. However, for ADF and PP unit root test, it is established at first difference that all series turn out to be stationary at a 1% significance level except urbanization. The exceptional revelation here is that urbanization is stationary at level form but turns non-stationary at first difference. This could be due to variation or drift characteristic of time series data noted by Gujarati (2009). In addition, only GDP fails to be stationary at level but turns stationary at first difference. The result shows a different order of integration which suggests the adoption of the autoregressive distributed lag (ARDL) bound test as the most suitable method.

The lag length (Table 4) in this study is selected because all of the sequential modified likelihood ratio test statistic (LR, FPE, AIC, SC, and HQ) unanimously generated a lag length of one. Thus, lag one is deemed most appropriate for this study since there is no conflicting interest among sequential modified likelihood ratio test statistic.

Table 3 Non-stationarity test (ADF and PP)

Statistics (Level)	LNCO ₂	LNGDP	LNFDI	LNURB	LNCOAL
τ _T (ADF)	- 1.142	- 1.384	- 3.901**	- 3.759**	- 1.039
τ _μ (ADF)	- 3.159**	- 0.874	- 3.575**	- 0.129	- 3.165**
τ (ADF)	3.690	0.599	- 3.303***	2.009	2.871
τ _T (PP)	- 1.075	- 1.073	- 3.781**	- 3.455*	- 0.9439
τ _μ (PP)	- 3.320**	- 0.605	- 3.475**	2.252	- 3.321**
τ (PP)	3.186	0.855	- 3.100***	6.357	2.551
Statistics (first difference)	LNGDP	LNFDI	LNFDI	LNURB	LNCOAL
τ _T (ADF)	- 6.961***	- 4.355***	- 4.524***	- 0.921	- 6.867***
τ _μ (ADF)	- 6.008***	- 4.265***	- 8.182***	- 1.873	- 5.934***
τ (ADF)	- 4.895***	- 4.253***	- 8.305***	- 0.129	- 5.185***
τ _T (PP)	- 6.975***	- 4.301***	- 8.458***	- 0.921	- 6.903***
τ _μ (PP)	- 6.004***	- 4.258***	- 8.606***	- 1.653	- 5.934***
τ (PP)	- 4.951***	- 4.243***	- 8.706***	0.097	- 5.205***

***, ** Significance at 0.01 and 0.05

Empirical analysis

Table 5 presents the empirical findings from the ARDL long-run and short-run test. The result reveals that economic expansion emits CO₂ significantly both in the long- and short- run. That is about 0.269% of carbon emissions in the short-run which is a consequence of the growth process in South Africa. The same is true of 0.187% for the long-run. This implies that economic expansion produces emission as its consequences. The impact of FDI inflows on CO₂ emissions is found to be significantly negative in both periods suggesting that FDI inflows rather slows down carbon emissions by about 0.002% and 0.005% in the two separate terms. The result further indicates that the contribution of urbanization to CO₂ is positively insignificant in the short-run but turns significant in the long-run. Urbanization significantly contributes to carbon emissions by 0.357% in the long-run which has policy implications for South Africa, pointing out that economic activities in the urban centers are in part responsible for carbon emissions. This is not far-fetched as activities in urban centers such as industrial operation are major producers of air pollution (carbon emissions) and water pollution. Thus, the government and stakeholders must partner to devise means of curtailing and efficiently managing the emissions produced from economic and commercial activities in the urban centers. A channel for proper disposal of the waste from the sources of

emission must be put in place. In a related development, coal consumption contributes significantly positive to carbon emissions both in the short- and long-run. About 0.771% of carbon emissions in South Africa is attributed to the operation of the coal sector in the short term, while in the distance term coal accounts for about 0.865% carbon emissions in the economy. The revelation from this test shows that coal consumption proves to be the highest emitter of CO₂ in South Africa. The implication is that the government must implement a conservation policy to lessen carbon emissions or risk pending danger of environmental degradation. On the other hand, after the rejection of the null hypothesis at 10, 5, and 1%, the cointegration bound test as presented in Table 6 reveals that the series converges in the long-run quickly with a high speed of adjustment of ~ 51%, as established by the error correction term (ECT). This implies that the short-run disturbance between the series could be corrected in the nearest future. The diagnostic test as presented in part B of Table 5 reveals that the functional model of the study is free from model specification errors. The CUSUM and CUSUMSQ presented in Figs. 2 and 3 indicate that the model is stable—as the blue line is properly fitted into the critical boundary (Emir and Bekun 2019).

The results from the TY Granger causality test in Table 7 reveal a one-way link only from GDP to CO₂ emissions as supported by Govindaraju and Tang (2013) in the case of

Table 4 Lag length criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	137.6040	NA	3.52e-10	- 7.577374	- 7.355182	- 7.500673
1	448.7944	515.6868*	2.83e-17*	- 23.93111*	- 22.59795*	- 23.47090*

***** Author’s computation is significant at 0.01 and 0.05

Table 5 ARDL result $CO_2 = f(\text{GDP, FDI, URB, and coal})$

Variables	Coefficient	SE	<i>t</i> statistic	<i>P</i> value
Short-run				
LNGDP	0.269***	0.062	4.339	0.000
LNFDI	− 0.002**	0.001	− 2.646	0.013
LNURB	0.934	1.260	0.741	0.465
LNCOAL	0.771***	0.027	28.616	0.000
ECT	− 0.512***	0.085	− 5.998	0.000
Long-run				
LNGDP	0.187***	0.044	4.299	0.0002
LNFDI	− 0.005**	0.002	− 2.596	0.0147
LNURB	0.357***	0.068	5.232	0.0000
LNCOAL	0.865***	0.022	40.003	0.0000
Diagnostic tests				
Tests	<i>F</i> statistic	Prob. value		
χ^2 Serial	1.189	0.320	F(2,27)	
χ^2 White	1.406	0.236	F(8,29)	
χ^2 Ramsey	0.027	0.974	F(2,27)	

***, **, * and represent 1, 5, and 10% respectively

China. Furthermore, for the case of South Africa, the unidirectional causality running from economic expansion to pollutant emissions is indicative to government officials of South Africa, as the result show that economic expansion is pollutant emission driven. This implies that economic growth in South Africa still exhibits the scale effect of growth trajectory, where the emphasis is on economic growth relative to the quality of the environment (Shahbaz and Sinha 2019; Saint Akadiri et al. 2019). As a matter of urgency, the government must review the consumption of carbon emitters such as coal—a critical factor in its growth equation to devise means of effective and efficient management—otherwise, the growth process may turn out to mar the economy in the long-run. The findings uncovered a one-way link running from FDI inflows to CO_2 implying that the major types of FDI flowing to South Africa drive CO_2 . The empirical evidence proves a one-way interaction flowing from urbanization to CO_2 . This is intuitively valid because urbanization connotes explosion of population and

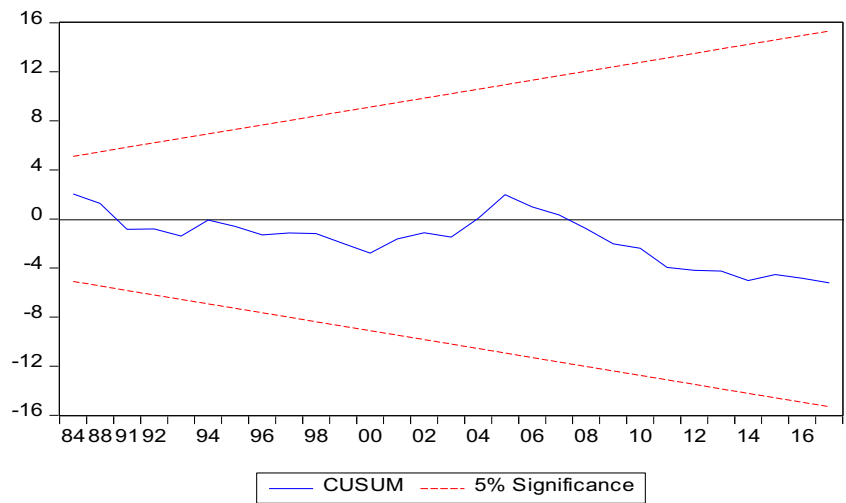
Table 6 ARDL Bounds test

Test stat.	Value	K
<i>F</i> stat	5.114	4
Critical value bounds		
Significance	I(0) bounds	I(1) bounds
10%	2.427	3.395
5%	2.893	4.000
1%	3.967	5.455

Author computation

commercial activities. Commercial activities which include high industrial productivity are most at time energy-intensive, hence are not free from carbon emissions. Another outcome from the findings also shows that a unidirectional link exists only from economic prosperity to FDI inflows. It signifies that the market size (economic expansion) in South Africa to a greater extent is responsible for the attraction of FDI inflows into the economy. This empirical evidence reflects the true nature of the South African economy which is known to be among the fast-emerging economies in Africa. Thus, the policymakers and the stakeholders need to do more on promoting the course of economic advancement, as well as, a stable macroeconomic environment to accommodate more FDI inflows and to provide a large market for their finished products. In addition, a peaceful environment in South Africa is not negotiable if the government is determined to give priority to the attraction of new investors into the economy, because no successful investor will risk its resources in an unstable economic or political environment. Similarly, a bidirectional interaction exists between coal consumption and CO_2 , whereas only one-way drive connects from GDP to coal consumption. This means that coal consumption in South Africa influences significantly to carbon emissions but not economic progress, contradicting the work of Bekun et al. (2019a, b) for South Africa but supports the conservation hypothesis and other empirical studies (see Zhang and Xu 2012). The implication is that conservation policy will be suitable for the South African economy without any side effect. A bidirectional relationship between GDP and urbanization implies that infrastructure and the general development of urban centers will be a thing of the past in the face of economic prosperity and vice versa. Another mutual benefit exists between urbanization and coal consumption. Notably, urbanization implies population explosion coupled with the expansion of productive economic activities which will, in turn, generate higher demand for energy for power supply. Thus, the reality of improving urban centers through infrastructural development will lead to an influence-derived demand for coal consumption through energy generation for power supply. The opposite holds when more energy is demanded. This is so because energy consumption is a critical factor that drives every segment of the economy. Adequate energy supply will not just boost industrial productivity but will increase the efficiency of the national economic productivity which transcends to improving lives and wellbeing. Finally, the findings further reveal a two-way interaction between FDI inflows and urbanization confirming the economic intuition that urbanization is an active player in attracting FDI inflows as validated by Nielsen et al. (2017) and Guimaraes et al. (2000). From both business and economic perspective, it can be deduced that functional urban centers with well-developed infrastructure are undoubtedly sight attraction for investors and vice versa, consistent with our *a priori* expectation.

Fig. 2 CUSUM



Conclusion

This study estimated the causal relationship between FDI inflows and economic advancement in a carbon function by incorporating urbanization, and coal consumption as additional variables, with specific emphasis on the role of urbanization. The results from the findings through Granger causality show that FDI does not drive economic advancement in South Africa, contradicting our *a priori* expectation. FDI was found to significantly hamper carbon emissions both in the short- and long-run, implying that FDI inflows to South Africa contribute to economic expansion through its positive impact on environmental quality. This calls for the attention of the authorities concern to take drastic and urgent measures for promoting the inflows of FDI into the economy. The stakeholders and managers of the economy must ensure that more FDI is allowed to flow into the country in order to achieve long-run economic acceleration through improvement in the environment. To this end, the authority concern could motivate new foreign investors through strategic and business incentives

such as a free license for operation and stability of the domestic currency. Furthermore, economic expansion promotes carbon emissions both in the short- and long-run, which implies that the growth path of the economy poses a great danger to its economic acceleration. The government must explore all possible ways to regulate the use of factors responsible for emissions in the economy among which is coal consumption. Economic growth must be monitored closely to avoid reversal reaction in the future. The findings showed that urbanization is a non-significant driver of carbon emissions in the short-run but turned significant in the long-run. In reality, urbanization connotes explosion in both population and commercial activities which industrialization is an integral part, thus, not surprising to confirm it as an emitter. This is a pointer that the authorities concern must put in place workable strategies to curb excess urban activities such as proper discharge of industrial pollutions, setting up of industrial zone away from human settlement. Similarly, the findings from the Granger causality show a two-way drive between urbanization and FDI inflows, implying that urban development in South Africa plays a vital

Fig. 3 CUSUMSQ

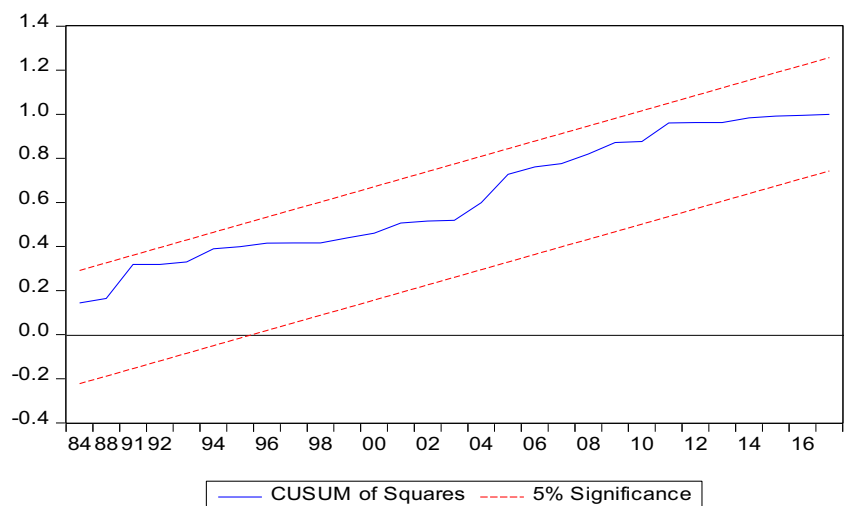


Table 7 Granger block exogeneity results

Excluded	Chi-sq	df	Prob.
Dependent variable LNCO2			
LNGDP	170.455 ^{****}	3	0.0000
LNFDI	161.444 ^{****}	3	0.0000
LNURB	131.633 ^{****}	3	0.0000
LNCOAL	25.905 ^{****}		0.0000
All	776.994 ^{****}	12	0.0000
Dependent variable LNGDP			
LNCO2	2.732	3	0.434
LNFDI	5.762	3	0.124
LNURB	36.109 ^{****}	3	0.000
LNCOAL	2.837	3	0.418
All	126.107 ^{****}	12	0.000
Dependent variable LNFDI			
LNCO2	3.967	3	0.265
LNGDP	9.588 ^{**}	3	0.022
LNURB	7.759 ^{**}	3	0.051
LNCOAL	4.546	3	0.208
All	49.526 ^{****}	12	0.000
Dependent variable LNURB			
LNCO2	1.394	3	0.7070
LNGDP	10.462 ^{**}	3	0.0150
LNFDI	7.784 ^{**}	3	0.0507
LNCOAL	3.992	3	0.2624
All	249.016 ^{****}	12	0.0000
Dependent variable LNCOAL			
LNCO2	17.437 ^{****}	3	0.000
LNGDP	74.545 ^{****}	3	0.000
LNFDI	79.077 ^{****}	3	0.000
LNURB	58.793 ^{****}	3	0.000
All	283.716 ^{****}	12	0.000

**** Significance at 0.01 and 0.05

role in promoting the course of FDI inflow into the economy. The government of South Africa must be guided by this evidence in placing priorities in terms of resource allocation. Both attention and adequate resources must be shifted to promote the course of urban development to attract significant FDI into the economy. The government of the day must embark on strategic policies such as sitting of the industrial zone and embarking on infrastructure improvement as a matter of necessity. On the other hand, a one-way link running from GDP to coal consumption is consistent with the conservative hypothesis. Similarly, the bidirectional link between coal consumption and CO₂ suggests that the former is an emitter. The empirical reality from this study speaks volume, showing that coal consumption promotes CO₂ emissions but not economic growth. Thus, embarking on effective conservation policy is not optional in the quest of South Africa to achieve economic prosperity and maintain a dynamically healthy economy.

Conclusively, urgent priority must be given to conservative policy to avoid the reality of the impending environmental degradation through incessant carbon emission. This is instructive; however, care must be taken to manage the usage of the carbon emitters such as coal, FDI, urban development, and economic prosperity. Because economic growth itself is an emitter, attention must be drawn to the necessary measures that will efficiently and effectively manage the path of economic prosperity; otherwise, in the long-run, economic advancement itself will turn out to be a curse rather than a blessing through environmental degradation caused by emissions.

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