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The capital investment channel of environmental improvement: evidence from BRICS

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Abstract This study focuses on the channel for improving environmental quality in Brazil, Russia, India, China and South Africa (BRICS). Hence, we interact non-renewable electricity consumption with capital investment to determine the mediating role of capital investment in the nexus between electricity consumption and carbon emission in BRICS. This study applies the fully modified and the dynamic ordinary least squares techniques to conduct this scientific enquiry, and the result suggests that electricity consumption and growth positively and significantly enhance the level of emissions, while capital investment significantly reduces the level of emissions in BRICS. Also, capital investment interacts with non-renewable electricity consumption to improve environmental quality in both approaches employed, thereby reversing the earlier increase in emissions caused by electricity consumption. In addition, we confirm the proposition of the environmental Kuznets curve in BRICS and conclude that capital investment is an important channel for improving environmental quality.

Keywords Electricity consumption · Capital investment · Growth · Environmental quality

JEL Classification Q43 · Q53 · Q32 · F43

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1 Introduction

The issue of concern to several economies is that of global warming. The quality of the environment in facilitating high standards for the welfare of the citizenry cannot be overemphasised. Economic literature often traces the high level of carbon emissions to economic growth. Such can originate from the increase in the pace of population growth that has necessitated the felling of trees and overall biodiversity depletion to accommodate the growing population (Eregha and Nwokoma 2014; Mesagan 2015a). Similarly, as the economy grows in terms of gross domestic product (GDP) or increases in the level of investment, it goes with environmental depletion by increasing the level of carbon emissions associated with industrial effluents discharged in the environment. As a matter of fact, the discourse on economic growth, electricity consumption and green house gas (GHG) emissions has received attention from several studies, which include: Lean and Smyth (2010), Apergis et al. (2010), Al-mulali (2011), Ozturk and Uddin (2012), Akpan and Akpan (2012), Cowan et al. (2014).

Moreover, the nature and quality of investment inflow goes a long way to influence the amount of emissions in that country. This is what gives rise to the polluter haven concept that is often attributed to the relocation of emission-producing firms from the advanced to less developed countries. For instance, the pollution haven hypothesis suggests that dirty industries shift their base to less developed countries from developed nations to circumvent the strict environmental laws in the latter (Letchumanan and Kodama 2000; Blomquist and Cave 2008). It thus follows that capital investment is often associated with some level of emissions, especially in developing economies. Determining the role of capital investment on environmental quality in emerging economies, especially in BRICS, is very crucial, and it is in response to the 5th BRICS Summit held in Durban, South Africa in 2013. At that Summit, the issue of climate change was considered as a major problem facing Brazil, Russia, India, China and South Africa, in their quest to achieve sustainable development (Cowan et al. 2014).

The pace of economic growth in BRICS coupled with the fact that Brazil, Russia, India, China and South Africa up till date depend largely on fossil fuels to generate their electricity, means that electricity consumption in BRICS fuels the level of emission and consequently, global warming (Cowan et al. 2014). In the same vein, electricity consumption has been pointed as a major contributor to the level of greenhouse gases all over the world. For instance, Zhang and Cheng (2009) confirmed that energy consumption unidirectionally caused CO_2 emissions in China, while Lean and Smyth (2010) observed that there is a positive association between electricity consumption and CO_2 emissions in the ASEAN economies. This is said to be the case especially in countries that have not been able to source the generation of their electricity from renewable sources like solar, coal and hydropower. Available evidences depict that in 2015, in terms of electricity generated from fossil fuels, Russia generated about 87.9% and its CO_2 emission was 1, 521 million tonnes (MT), Brazil generated 66.7% and its CO_2 emission was 491.3 MT, India generated 92.5% and its CO_2 emission was 2, 157.4 MT, China generated 88.2% and its CO_2 emission was 9, 164.5 MT, while South Africa generated 96.5% and its CO_2 emission was 421.8 MT (BP Statistical Review 2017). In the economic literature, several studies have lent credence to non-renewable electricity consumption being a major causal factor driving greenhouse gas emissions (see, Lean and Smyth 2010; Menyah and Wolde-Rufael 2010; Li et al. 2011; Al-mulali 2011; Akpan and Akpan 2012; Farhani and Ben Rejeb 2012; Salahuddin et al. 2015; Dogan and Seker 2016; Bento and Moutinho 2016; Nilsson et al. 2015; Cho et al.

2016). Other studies have also linked the amount of greenhouse gas emissions to the inflow of inappropriate technology for investment in developing countries (such as Cole and Elliott 2005; He 2006; Chung 2014; Chaturvedi et al. 2014; Mesagan 2015b; Tang and Tan 2015; Zhang and Zhou 2016), thereby making developing countries become specialists in the production of dirty goods, unlike their developed counterparts.

Considering these views, one major channel in the electricity consumption and environment nexus often omitted in the literature is capital investment. The quality of investment domiciled in a country provides the appropriate channel through which environmental quality can either be enhanced or exacerbated. As noted in Sims et al. (2003) and Tang and Tan (2015), investment can be used to neutralise the threat of carbon emissions. Hence, it is important to include it in the model for BRICS to confirm whether the result could withstand empirical scrutiny. This is the main essence of the present inquiry and thus serves as an important contribution to the literature. More so, owing to the lack of consensus in the literature about the effect electricity consumption has on carbon emissions, this study becomes very important as it takes a position by analysing the situation in Brazil, Russia, India, China and South Africa. Moreover, BRICS is focussed on since they generate most of their electricity from fossil fuels, which have been found to contribute significantly to CO_2 emissions. Also, global warming abatement is top on their priority list (Cowan et al. 2014). As observed by Morazan et al. (2012), the pace of capital investment in BRICS is among the fastest when compared with other countries of the world. Hence, these four variables (electricity consumption, growth, capital investment and CO_2 emissions) occupy the heart of this research for the bloc (BRICS). The study, therefore, sets out to determine the effect of electricity consumption on carbon emissions in BRICS. It aims at examining the impact of capital investment on carbon emissions in BRICS. It attempts to find out if non-renewable electricity consumption can interact with capital investment to improve environmental quality in BRICS as well as tests the existence of the environmental Kuznets curve (EKC) among the five countries. To this end, country-specific results will be obtained to determine what is the situation in each of the five countries selected. The rest of this study is organised as follows. Review of relevant theories and studies is presented in Sect. 2, while stylised facts of electricity consumption and capital investment are presented in Sect. 3. Moreover, data sources and research methodology involving the panel cointegration techniques (fully modified and dynamic OLS approaches) developed by Pedroni (1999, 2000) are presented in Sect. 4; the empirical result is presented in Sect. 5, while the summary and conclusion are presented in Sect. 6.

2 Literature review

2.1 Brief theoretical review

In economic literature, several theories have been able to trace the quality of environment to growth and investment. One of these theories is the "pollution haven hypothesis" (PHH).[1] As pointed out in Gray (2002), Temurshoev (2006) and Greaker (2007), the PHH

[1] The Pollution haven hypothesis opines that to set up international subsidiaries, firms always search for countries where they can easily operate at the lowest possible costs either in terms of obtaining cheap resources or in terms of circumventing the payment of carbon tax.

suggests that capital investments do flow into countries with lax environmental laws.[2] This is often the case as investors, especially foreign investors, prefer to take advantage of countries where their environmental laws are not too strong to locate their industries. This enables them to operate cheaply in terms of cost and expand their profit margins. According to the PHH, since environmental laws in developed countries are somewhat stricter than those in less developed economies, high-pollution-emitting industries in the North (developed countries) do normally relocate to the South (developing countries) to take advantage of the situation, consequently resulting into "Polluter Haven" in less developed economies (Chichinisky 1994; Gray 2002; Eskeland and Harrison 2003; Cole 2004; Greaker 2007; Eregha and Nwokoma 2014). This means that more growth and investment coupled with weak implementation of environmental policies in developing countries put the life of the citizens in danger. Another closely related theory of growth and environment is the EKC. The EKC suggests that at the early stage of development, growth in GDP goes hand in hand with increases in the level of environmental pollution and carbon emission. This emission level reaches a threshold and begins to fall even as GDP continues to rise (Stern, 2003, 2004; Dasgupta et al. 2002). The EKC proposes an inverted "*U*"-shaped curve to depict the relationship between carbon emission and economic growth. The implication of this is that at the early stage of development, the level of emission rises with an increase in GDP, but as the economy becomes buoyant and can afford the means to control emission level through technological advancement, emission reduces, and environmental quality improves in the long run.

Furthermore, the "Race to the Bottom" theory focuses on the role foreign investment plays in ensuring a quality environment. According to the theory, governments can on their own deliberately lower their countries' environmental laws to attract investment from foreign countries (see Baumol and Oates 1988; Gray 2002; Greaker 2007). The Race to the Bottom opines that national governments often do this to enhance growth during the early stage of development. However, as their economies become stable financially and economically, they then set up machinery to control emission levels better by tightening their environmental laws. This is also in consonance with the proposition of the EKC. On the other hand, however, the "Race to the Top" theory suggests that governments do not have any business lowering their environmental laws to attract investment. As postulated in the Porter Hypothesis,[3] a very strong policy on the environment can help to enhance market competition. Market competition coupled with stronger environmental regulations help to develop the spirit of innovation among firms, guarantee efficiency and attract more local and foreign investors. This is what Gray (2002) and Copeland and Taylor (2004) have termed the "pollution halo theory".[4] Zhang and Zhou (2016) also provided support for the pollution halo theory.

[2] Lax environmental laws: This is a situation whereby a country's environmental policies are either poorly implemented or do not exist at all. This can make such country become a haven for environmental pollution.

[3] Porter hypothesis was articulated by Michael Porter in 1995, and it suggests that a tight environmental regulation can help to stimulate innovative consciousness in a country and induce efficiency needed for generating commercial competitiveness.

[4] Pollution halo theory reveals that carbon emissions can be reduced through the transfer of advanced technology triggered by foreign direct investment to host countries.

2.2 Empirical review

The literature on the relationship between electricity consumption, growth and environment is numerous (for instance, Tiwari 2012; Cowan et al. 2014; Farhani and Shahbaz 2014; Salahuddin et al. 2015; Dogan and Seker 2016; Bento and Moutinho 2016). Some have been able to link the poor quality of environment to electricity consumption (see Jung 1996; Bernard et al. 2004; Nilsson et al. 2015; Cho et al. 2016), while others have traced high level of GHG emissions to economic growth issue (Seetanah and Vinesh 2012; Safdari et al. 2013; Mesagan 2015a; Narayan et al. 2016; Deviren and Deviren 2016).

For country-specific studies on electricity consumption, growth and environment, Tiwari (2012) employed a multivariate framework and a new time series approach to model the dynamics of growth, emissions and energy consumption in India. The static causality analysis employed showed that a unidirectional causality runs from carbon emission to economic growth and that there is bidirectional causality between energy consumption and emissions in India. In the dynamic causality reported, carbon emission explained more forecast error variance of output than energy consumption, while energy consumption explained more error variance of emission than GDP. Bento and Moutinho (2016) tested for structural breaks and found cointegration between renewable and non-renewable electricity production, growth, international trade and CO_2 emissions in Italy. Also, renewable electricity production reduced CO_2 emissions both in the short run and in the long run, while trade only impacted emissions in the long run. Furthermore, output unidirectionally caused renewable electricity production, while non-renewable electricity also intensified renewable electricity in the long run. For the cross-country studies, Cowan et al. (2014) extended the discussion to BRICS and found support for the feedback hypothesis and conservation hypothesis in Russia and South Africa, respectively. However, in Brazil, India and China, the neutrality hypothesis was confirmed alluding to the fact that in the three countries, electricity consumption and growth are insensitive to each other. Farhani and Shahbaz (2014) observed that renewable and non-renewable electricity contributed significantly to CO_2 emission in the Middle East and North African (MENA) countries. It also found unidirectional causality running from electricity consumption and growth to carbon emission in the short run, but bidirectional causality in the long run. Salahuddin et al. (2015) observed that the long-run relationship between electricity consumption, growth and emission in Gulf Cooperation Council (GCC) economies is robust and that output and electricity consumption positively and significantly enhanced emissions in the long run. Recent studies by Dogan and Seker (2016), as well as Bento and Moutinho (2016), reported contrasting results. Dogan and Seker (2016) decomposed energy consumption into renewable and non-renewable and observed that renewable energy, trade and financial development negatively enhanced the level of CO_2 emission, while non-renewable energy provided a positive impetus to emission level in the selected renewable energy countries.

In terms of the country-specific studies focusing on the relationship between electricity consumption and carbon emissions, Nilsson et al. (2015) assessed the relationship from the angle of the cost of residential electricity consumption and carbon emission in Sweden. It was observed that electricity costs fell slightly as households shifted their consumption of electricity to off-peak hours and carbon emission increased. However, in a recent study conducted in Japan by Cho et al. (2016), it was observed that CO_2 emission rose significantly as the country generated additional 4.3 million metric tons of carbon emission in 2011 owing to the singular decision to substitute fossil fuel for nuclear power after the Tohoku earthquake. Jung (1996) looked at greenhouse gas emissions and future energy consumption in the Republic of Korea. Employing a bottom-up approach, it was speculated that energy consumption and its associated emission could rise five times between 1992 and 2030, while growth was projected to rise by about six times during the same period. For the panel, Bernard et al. (2004) beamed searchlight on five regions in the US–Canada border and concluded that carbon emissions slightly reduced among the regions due to free trade and the amount of electricity consumed.

The last set of empirical studies focused on the relationship between growth and the level of emission. For the country-specific studies, Seetanah and Vinesh (2012) did not find the existence of EKC in their study on growth and greenhouse gas emissions in Mauritius even though the level of income emissions elasticity rose significantly over time. The reason given for this is Mauritius' inability to control its level of emission discharged over the last few decades. Safdari et al. (2013) conducted a similar study in Iran and observed that population growth, industrial activities and economic growth increased environmental damage. The causality analysis conducted showed the existence of bidirectional causality between carbon emission and economic growth in Iran. Mesagan (2015a) focused on the Nigerian economy and came up with the result that economic growth intensified the emission of carbon. It, therefore, called for the use of technologies that are environmentally friendly to promote green growth. For the cross-country studies, Narayan et al. (2016) focused on 181 countries and observed that an increase in growth over time reduced the amount of carbon emission, thereby providing support for the EKC hypothesis. Deviren and Deviren (2016) also gave credence to the link between economic growth and the level of carbon emission by researching into the topology, taxonomy and relationship in 33 countries. The results provided clear evidence that high level of CO_2 emission together with high income per capita was common among the selected countries.

From the foregoing, most of the previous studies that have looked into the issue of electricity consumption, growth and carbon emissions have based their analyses on the causality among the variables (like Cowan et al. 2014; Dogan and Seker 2016). This study deviates a little by focussing on the direct impact of growth and electricity consumption on the environment. Also, the inclusion of capital investment in this study is very important because investment is an important channel through which electricity consumption can affect CO_2 emission, as countries in BRICS have come to be associated with high level of investment. Therefore, omitting it as most of the previous studies (Jung 1996; Bernard et al. 2004; Tiwari 2012; Cowan et al. 2014; Farhani and Shahbaz 2014; Salahuddin et al. 2015; Dogan and Seker 2016; Bento and Moutinho 2016; Nilsson et al. 2015; Cho et al. 2016) have done can make the information provided in the study to be incomplete. Moreover, combining these four variables (CO_2 emission, electricity consumption, growth and investment) is very crucial since BRICS are among the world's top emerging economies coupled with the fact that the five countries generate most of their electricity from fossil fuels known for producing high level of carbon emissions, as stated in the introduction section of this study. Furthermore, the two panel cointegration techniques (FMOLS and DOLS approaches) of Pedroni (1999, 2000) was employed in the study not only to differentiate it from the causality analysis usually conducted by previously related studies, but also to enable us to determine jointly the country-specific impacts and the panel impact of electricity consumption and growth on CO_2 emission. To the best of our knowledge, a research of this sort has not been conducted in BRICS despite their fast growth rate. The only study that has attempted to bridge this gap (Cowan et al. 2014) only looked at the panel causality and did not also emphasise the effect of investment in the CO_2 emission model formulated for BRICS, this present study aims to fill this noticeable gap in the literature. This present study makes original contributions to the literature by presenting a framework for analysing the channel through which electricity consumption can be used

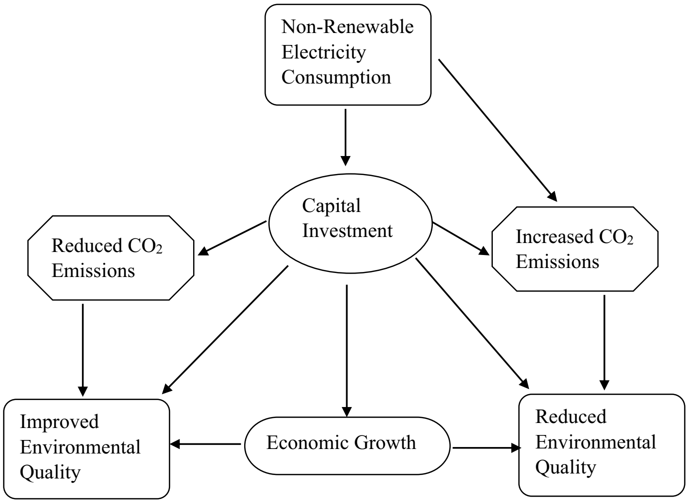

Fig. 1 Conceptual Framework for the study. *Source*: Authors' Computation (2017)

to improve the environment and by interacting electricity consumption with capital investment to determine whether it can reverse the negative impact of non-renewable electricity on the environment or sustain its positive impact on the environment.

3 Stylised facts of electricity consumption and CO_2 emissions

3.1 Framework for analysing the link between electricity consumption and environmental improvement

The main contribution of this study is in terms of the role of capital investment in environmental improvement. As depicted in Fig. 1, the quality of investment in a country determines the reduction or improvement in environmental quality. As reported in studies like Jung (1996), Zhang and Cheng (2009), Lean and Smyth (2010), Farhani and Shahbaz (2014), Salahuddin et al. (2015), and Cho et al. (2016), the consumption of non-renewable electricity increases carbon emissions and in turn reduces environmental quality. Similarly, the consumption of non-renewable electricity by heavy-duty capital investment provides a spur to increased carbon emissions and consequently reduces environmental quality. In studies like Bernard et al. (2004) and Safdari et al. (2013), inflows of trade and investment can help boost the level of economic growth, which has a positive or negative impact on the environment. According to Eregha and Mesagan (2017), energy consumption increases contribute greatly to economic growth and boost overall macroeconomic performance. For Safdari et al. (2013), industrial activities and economic growth increase environmental damage, while Bernard et al. (2004) suggested otherwise. As suggested by the EKC, economic growth reduces environmental quality at early production stages and improves environmental quality after the threshold level of emissions (Andreoni and Levinson, 2001). Also, Bento and Moutinho (2016) confirmed the EKC in their study by observing that economic growth produces less emission overtime, while Salahuddin et al. (2015) reported that both output and electricity consumption increases carbon emissions. Hence,

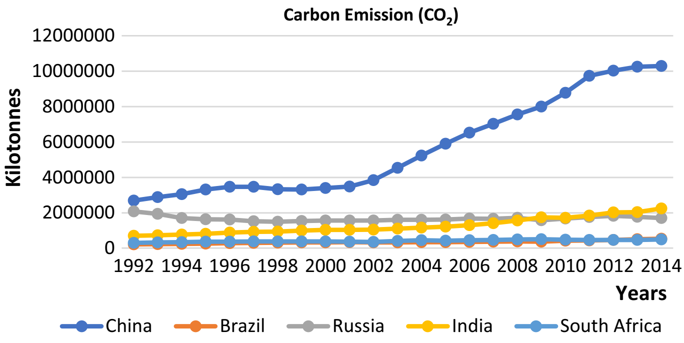

Fig. 2 Trend of CO_2 Emission. *Source*: Authors' Computation from WDI (2017)

when proper production technologies are attracted due to strong environmental regulations, capital investment generates the growth that can improve the environment and vice versa. Lastly, as observed in Bernard et al. (2004), strong environmental regulations and management make a country attractive to investments that reduce carbon emissions and improves environmental quality. To this end, it makes sense to report that capital investment inflow is an important channel through which environmental quality can be enhanced or reduced.

3.2 Trends of CO_2 emissions and electricity consumption in BRICS

In Fig. 2, the graphical description of carbon emissions among the five countries shows that China has the largest amount of CO_2 emissions in BRICS. It can be seen in Fig. 2 that over the study period between 1992 and 2014, the country's level of emission was highest. In 1992, the CO_2 emissions in China, Russia, India, South Africa and Brazil, in kilo tonnes, stood at about 2.69, 2.08, 0.69, 0.30, and 0.22 million, respectively. As noted in Fig. 2, the trend of CO_2 emission in China maintained a significant upward trend, which coincides with the period the country overtook America and the European Union as the world's largest emitter (Wilson 2014).

As at the end of 2014, CO_2 emission in China has risen to 10.29, 2.23 million for India in second place, Russia dropped slightly to third with CO_2 emission of 1.70 million, while that of Brazil increased slightly to 0.52 million and that of South Africa drastically reduced to 0.48 million kilotonnes. This means that South Africa has made an appreciable progress in reducing its CO_2 emissions over the study period. Considering the data, both South Africa and Russia were able to lower their emissions of carbon between 1992 and 2014, while emissions in China and India rose significantly. One main reason attributable to increase emissions in China is the level of industrial production in the country. It is, however, expected that China's short-term energy-intensity reduction target for the period of 2006–2010 and its long-term carbon intensity reduction target for 2020 can help to lower the upward trend. Also, in Fig. 2, both India and Russia have relatively high kilotonnes of CO_2 emissions compared to the emissions in South Africa and Brazil. Russia's high rate of income growth due to higher crude oil prices in the early 2000s and India's quest to boost its industrial growth account for its high contribution to global emissions. However, South Africa's Integrated Resource Electricity Plan (IRP), as well as Brazil's foray into

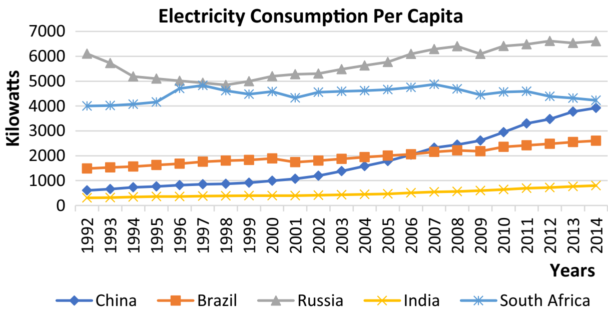

Fig. 3 Trend of electricity consumption. *Source*: Authors' computation from WDI (2017)

Table 1 Electricity consumption by fuel type and CO_2 emissions in BRICS. *Source*: Authors' Compilation from BP Statistical Review of World Energy (2017)

Countries	Electricity consumption (% of total)				Carbon emissions (million tonnes)	
	Fossil fuels	Renewables	Fossil fuels	Renewables		
	2015		2016		2015	2016
Brazil	66.7	33.3	63.2	36.8	491.3	458
Russia	87.9	12.1	87.2	12.8	1521.9	1490.1
India	92.5	7.5	92.5	7.5	2157.4	2271.1
China	88.2	11.8	87.0	13.0	9164.5	9123
South Africa	96.5	3.5	95.3	4.7	421.8	425.7

biofuels production, helps both countries to be able to achieve a lower level of CO_2 emissions among BRICS countries.

Moreover, the trend of electricity consumption in BRICS as shown in Fig. 3 confirmed Russia as the country with the highest non-renewable electricity consumption per capita. This is followed by South Africa and then Brazil until it was recently overtaken by China, non-renewable electricity consumption in India remained the smallest in BRICS. In 1992, electricity consumption per capita in Russia is 6, 107 kW, while it is 3, 999 kW in South Africa, 1, 491 kW in Brazil, 604 kW in China, and 305 kW in both India. In 2014, according to the World Bank (WDI 2017), Russia's electricity consumption per capita increased to 6, 602 kW, while that of South Africa increased to 4, 228. China's electricity consumption overtook Brazil and stood at 3, 927 kW, while Brazil's electricity consumption remained 2, 601 and that in India remained the lowest at 805 kW at the end of 2014. From the year 2000 up till date, China's electricity consumption per capita continues to rise significantly and this is in tandem with the trend of carbon emission, which is not just the highest in BRICS but also continues to maintain an upward trend.

Among the five countries considered in the study, non-renewable electricity consumption in Russia maintained dominant status all through the study period. Comparing Figs. 2 and 3, we found that China's CO_2 emissions remained the highest although its electricity generation from fossil fuels ranks 3rd in BRICS, while Russia, which had the third highest CO_2 emissions in BRICS, has the highest electricity consumption from fossil energy. The implication is that there is a missing link in the non-renewable electricity consumption and CO_2 emission nexus. This is explained by the quality of capital investment inflows to these countries, and this is what the present study attempts to unravel. For Russia, the country is one of the World's largest crude oil producer; hence, the reason for having non-renewable electricity consumption among the five countries.

Presented in Table 1 are the data on electricity consumption in BRICS based on fuel type and carbon emission. In the table, Brazil sourced 66.7 and 33.3% of electricity from non-renewable and renewable energy, respectively, in 2015, while it reduced its fossil energy consumption to 63.2% in 2016 and carbon emissions dropped from 491.3 to 458 MT. Brazil is able to reduce fossil fuel energy by producing biofuels at a very large quantity, and this makes the country to generate the highest proportion of its electricity from renewable energy in the cases of 2015 and 2016 presented. Russia reduced its non-renewable electricity consumption from 87.9% in 2015 to 87.2% in 2016 and its carbon emissions dropped from 1521.9 to 1490 MT. Also, China was able to reduce its non-renewable electricity consumption from 88.2% in 2015 to 87% in 2016 but emissions reduced marginally from 9164 to 9123 MT. However, South Africa reduced consumption of non-renewable electricity from 96.5% to 95.3%, but emissions increased slightly from 421.7 to 425.8 MT, while India about maintained the same ratio of 92.5% of non-renewable electricity consumption but CO_2 emissions increased 2157.4 to 2271.1 MT.

3.3 Economic processes relating to electricity consumption and CO_2 emissions abatement in BRICS

In the 2000s, China's energy consumption increased significantly, while its carbon emission rose too, and by 2007, China's contribution to global CO_2 emission overtook that of the USA, thereby making China the largest contributors to world CO_2 emissions. For instance, specifically in 2002, CO_2 emission in China was 50% lesser than those in America, but in about one decade later, China's CO_2 emission was twice higher than that of America and also higher than those in the European Union countries (Wilson 2014). During the period, China acted to lower its energy and emission intensity by developing an energy-intensity reduction short-term target for the period of 2006 to 2010 and a 2020 long-term carbon intensity reduction target as well (Zhou et al. 2011). According to Grubb et al. (2015), it was reported that the industrial sector accounted for over 50% of the total final energy consumed in China, which contrasted with historical perspectives where countries shift to service-based structures from energy-intensive industrial bases as per-capita income increases. Similarly, Russia which enjoyed increases in income per capita owing to the rise in global oil price in the early 2000s is one of the world's largest emitters too. According to the Climate Action Tracker (CAT 2017), Russia presented a national policy that could delay the ratification of the Paris Agreement[5] till 2019. In terms of the Intended National Determined Contribution (INDC), the Russian Federation's current INDC emissions reduction target is higher than the proposed level in the Paris Agreement and is one of the weakest by any national government. However, Russia has now projected to reduce its CO_2 emissions to 70% of the 1990 levels by 2030. For Brazil, the production of biofuel helped to diversify its energy sources and reduce its CO_2 emissions.

[5] The Paris Agreement is built on the United Nations Framework Convention on Climate Change (known as "the Convention". The Convention encourages every nation to participate in the common goal of battling climate change and keep world temperature below 2 °C and further strive to lower future temperature increases well below 1.5 °C.

According to Masiero (2011), Brazil is one of the leading economies in developing ethanol to provide an economically viable option to fossil fuels to diversify the country's energy sources. In 1979, Brazil developed its first large-scale production of vehicles that can operate with ethanol as fuel, and since then, the country has risen to become a leading producer of biofuels globally and it has one of the highest ratios of renewable energy in its energy mix as at today. The recent global economic recession, which necessitated about 50% budget cuts to the Brazilian Environment Ministry, coupled with increasing deforestation since 2016, has contributed to the country's level of emissions in the current year (CAT 2017). For India, its emissions per capita are currently one-third of the world's average and far lesser than those of the US and China courtesy of its energy sector that depends on around 60% coal. However, in absolute terms, the country currently accounts for about 4.5% of world's greenhouse gas concentrations behind China, the USA and the European Union. Also, the country's quest to boost development by industrialising rapidly extremely increases its fossil fuel energy demand. To ensure diversification of its energy mix and reduce CO_2 emissions as a ratio of its GDP between 33% and 35% from 2005 levels by 2030, the country is set to achieve 175 gigawatts (GW) of renewable energy by 2022 and source about 40% of its electricity from renewable energy, mostly from solar, by 2030. It also plans to permit the sale of only electric and battery-driven vehicles beginning from 2030 (Mazumdaru 2017).

Lastly, CAT (2017) opined that South Africa is close to achieving its 2030 target of emissions reduction. The country sets a robust renewable energy target for 2030, with its Integrated Resource Electricity Plan (IRP) for the period of 2010–2030. The IRP has set a renewable energy target of 17.8 GW for 2030. Similarly, its Nationally Determined Contribution (NDC) sets a target to reduce GHG emissions to between 398 and 614 MT from 2025 to 2030. According to CAT (2017), the country will achieve its emissions reduction target with its low economic growth, caused by economic recessions, and its currently implemented policies. However, CAT has rated South Africa's effort as insufficient because coal generation may grow at a similar rate to the renewable energy growth if the country's economy grows again, thereby causing levels of emission up to 2030 to rise significantly.

4 Research methodology

This empirical research considers the role of electricity consumption and growth in the abatement of carbon emission in Brazil, Russia, India, China and South Africa between 1992 and 2014. Following the empirical studies of Stern (2003, 2004), Farhani and Shahbaz (2014) as well as Dogan and Seker (2016) and the need to test the proposition of the environmental Kuznets curve (EKC) hypothesis in BRICS, the empirical model is specified as follows:

$$(\mathrm{CO}_2)_{it} = \beta_0 + \beta_1 Y_{it} + \beta_1 Y_{it}^2 + \varepsilon_{it}. \tag{1}$$

Equation (1) is the EKC model as specified in Stern (2003, 2004) where the level of carbon emission (CO_2) depends on the level of output per capita (Y). It is normally specified as a quadratic function because the EKC suggests that at the early stage of development, output positive impacts carbon emission which gets to its peak and begins to decline even as output continues to increase. Therefore, for this proposition to be confirmed in BRICS, the coefficient of Y will be positive, while that of Y^2 will be negative. "i" is the number of cross sections, "t" is the time period, and "ε" is the white noise error term.

For this study, Eq. (2) modifies the EKC model in Eq. (1) to accommodate electricity consumption (EC) per capita as employed in recent studies (see Farhani and Shahbaz 2014; Dogan and Seker 2016). Also, capital investment (CI), which is an important channel through which electricity consumption and growth can affect carbon emission, is brought into the model and the interaction term between electricity consumption and capital investment (ECI) is also brought into the model to help determine the joint impact of both electricity consumption and gross capital formation on carbon emissions in BRICS. Both capital investment (CI) and its interaction with electricity consumption (ECI) are contributions of the study to literature.

$$(\mathrm{CO}_2)_{it} = \beta_0 + \beta_1 Y_{it} + \beta_1 Y_{it}^2 + \beta_3 \mathrm{EC}_{it} + \beta_4 \mathrm{CI}_{it} + \varepsilon_{it} \tag{2}$$

In Eqs. (1) and (2), β_0 is the intercept term, while β_1, β_2, β_3, β_4, β_5 are the coefficients of the various explanatory variables as defined. If $\beta_1 > 0$, and $\beta_2 < 0$, the EKC proposition holds in BRICS. We are expecting β_3 to be positive since it is non-renewable electricity consumption which is highly emission intensifying. The coefficients of β_4 and β_5 can be positive or negative depending on the net effect of capital investment on carbon emissions and that of electricity consumption and capital investment on carbon emissions when interacted.

To conduct the study, we extract data from the World Development Indicators (WDI 2017) of the World Bank. Data employed in the study include carbon emission (CO_2) per capita measured in kilo tonnes, real GDP per capita (Y), electricity consumption per capita (EC) measured in kilowatts, capital investment (CI) which is captured with gross capital formation as a ratio of GDP and the interaction term between electricity consumption and capital investment (ECI). The various data extracted are analysed with the fully modified (FMOLS) and the dynamic OLS (DOLS) approaches. Both approaches are the panel cointegration methods of estimation employed in Pedroni (1999, 2000). The FMOLS and the DOLS assist in correcting the endogeneity and serial correlation in long-run relationships associated with the regular pooled OLS. To this end, equations of the FMOLS and the DOLS are presented as follows:

$$\mathrm{CO}_{2it} = \alpha_i + \beta_i x_{it} + \mu_{it} \tag{3}$$

where CO_{2it} is as earlier defined and x_{it} is the vector of independent variables which include electricity consumption per capita, capital investment, real output per capita and the interaction of electricity consumption and capital investment, while μ is the error term. CO_{2it} and x_{it} are cointegrated with slopes β_i, which may or may not be homogeneous across the countries i. If we denote the stationary vector of residuals estimated from the cointegrating regression and the differences in x with $\xi_{it} = (\hat{\mu}_{it,} \Delta x_{it})$ and we also denote the long-run covariance matrix for the vector process with $\Omega_i = \lim T \rightarrow \infty E\left[T^{-1}\left(\sum_{t=1}^{T} \xi_{it}\right)\left(\sum_{t=1}^{T} \xi_{it}'\right)\right]$, we can then have $\Omega_i = \Omega_i' + \Gamma_i + \Gamma_i'$ where Ω_i^0 is the contemporaneous covariance and Γ_i is the weighted sum of auto covariance.

As employed in Pedroni (1999, 2000), the between-dimension, group mean panel FMOLS estimator is therefore specified as:

$$\hat{\beta}_{\mathrm{GFM}}^{*} = N^{-1} \sum_{i=1}^{N} \left(\sum_{i=1}^{N} (x_{it} - \bar{x}_i)^2 \right)^{-1} * \left(\sum_{i=1}^{N} (x_{it} - \bar{x}_i)\mathrm{CO}_{2it}^{*} - T\widehat{\mathrm{CO}}_{2i} \right). \tag{4}$$

$\hat{\beta}_{\mathrm{GFM}}^{*}$ is the group FMOLS estimator or simply known as the between-dimension estimator. It is obtained by finding the average of all coefficients of the regressors in the model.

Where $CO^*_{2it} = \left(CO_{2it} - \overline{CO}_{2i}\right) - \frac{\hat{\Omega}_{21i}}{\hat{\Omega}_{22i}}\Delta x_{it}$, and $\widehat{CO}_2 = \hat{\Gamma}_{21i} + \hat{\Omega}^0_{21i} - \frac{\hat{\Omega}_{21i}}{\hat{\Omega}_{22i}}\left(\hat{\Gamma}_{22i} + \hat{\Omega}^0_{22i}\right)$.

We can then construct the between-dimension estimator as $\hat{\beta}^*_{\mathrm{GFM}} = N^{-1}\sum_{i=1}^{N}\hat{\beta}^*_{\mathrm{FM}_i}$ where $\hat{\beta}^*_{\mathrm{FM}_i}$ is the conventional FMOLS estimator applied to the ith member of the panel. The t-statistics for the between-dimension estimator is then given as: $t_{\beta^*_{\mathrm{GFM}}} = N^{-1/2}\sum_{t=1}^{N} t_{\hat{\beta}^*_{\mathrm{FM}i}}$ where $t_{\hat{\beta}^*_{\mathrm{FM}i}} = \left(\hat{\beta}^*_{\mathrm{FM},i} - \beta_0\right)\left(\hat{\Omega}^{-1}_{11i}\sum_{t=1}^{T}(x_{it} - \bar{x}_i)^2\right)^{1/2}$.

Moreover, the between-dimension, group mean panel for the dynamic OLS estimator is specified in Eq. (5). To start with, we augment the cointegrating regression with the lead and lagged differences of the regressor to enable us to control for endogenous feedback effect that is like the one in the procedure of the FMOLS:

$$CO_{2it} = \alpha_i + \beta_i x_{it} + \sum_{k=-k_i}^{k_i} \gamma_{it}\Delta x_{it-k} + \mu_{it}. \tag{5}$$

From Eq. (5), the group mean panel DOLS estimator is specified as; $\hat{\beta}^*_{\mathrm{GD}} = \left[N^{-1}\sum_{i=1}^{N}\left(\sum_{t=1}^{T} z_{it}z'_{it}\right)^{-1}\left(\sum_{t=1}^{T} z_{it}CO_{2it}\right)\right]_1$ where, z_{it} is the $2(k+1) * 1$ vector of explanatory variables. $z_{it} = (x_{it} - \bar{x}_i), \Delta x_{it-k,\ldots,}\Delta x_{it+k}$; $CO_{2it} = CO_{2it} - C\overline{O}_{2i}$, and subscript 1 outside the brackets shows that we are using only opening element of the vector to determine the pooled slope coefficient. The between-dimension estimator is then constructed as $\beta^*_{\mathrm{GD}} = N^{-1}\sum_{i=1}^{N}\beta^*_{D,i}$ where $\beta^*_{D,i}$ is the conventional dynamic OLS estimator that is applied to the ith panel member. It is obtained by finding the average of all coefficients of the regressors in the model. If we then take $\delta_i^2 = \lim T \to \infty E\left[T^{-1}\left(\sum_{t=1}^{T}\hat{\mu} *_{it}\right)^2\right]$ as the long-run variance of the residuals from the dynamic OLS, the DOLS' t-statistics for the between-dimension estimator becomes:

$$t_{\hat{\beta}^*_{\mathrm{GD}}} = N^{-1/2}\sum_{i=1}^{N} t_{\hat{\beta}^*_{D,i}} \quad \text{where,}\ t_{\hat{\beta}^*_{D,i}} = \left(\hat{\beta}^*_{D,i} - \beta_0\right)\left(\hat{\delta}_i^{-2}\sum_{t=1}^{T}\left(x_{it} - \bar{x}_i\right)^2\right)^{1/2}.$$

Anytime a study applies cointegration tests to long-run hypotheses in aggregate panel data, the main challenge will be to construct the regressors in such a way that it does not inhibit the transitional dynamics to be similar among the countries selected in the panel. A way out as suggested by Bangake and Eggoh (2011) is to employ the fundamental theme for the panel DOLS and FMOLS approaches by pooling only that information which concerns the long-run hypothesis of interest and permits the short-run changes to be potentially heterogeneous.

Table 2 Panel unit root

Variables	Heterogeneous unit root process				Homogeneous unit root process			
	Level		1st diff		Level		1st diff	
	PP-fisher	IPS	PP-fisher	IPS	Breitung	LLC	Breitung	LLC
CI	9.86	− 0.53	79.06***	− 3.65***	− 1.63	− 0.92	− 3.36***	− 2.37***
CO_2	44.19***	− 1.50	40.77***	− 2.43***	0.22	− 1.99**	− 3.48***	− 2.68***
EC	5.40	0.20	34.04***	− 4.26***	0.95	0.10	− 5.36***	− 6.62***
RGDP	7.29	1.15	20.06**	− 1.89**	4.13	0.79	− 2.01**	− 3.13***
ECI	8.64	− 0.52	60.74***	− 5.25***	0.27	− 0.65	− 4.27***	− 5.19***

IPS Im, Pesaran and Shin, *LLC* Levin, Lin and Chu

***1% significant; **5% significant

Table 3 Pedroni residual cointegration test

Between-dimension		Within-dimension		
	Statistic		Statistic	Weighted statistic
Group rho	0.98	Panel v-stat.	− 1.10	0.95
Group PP	13.98***	Panel rho-stat.	− 2.35	− 2.42***
Group ADF	− 3.30***	Panel PP-stat.	− 11.16	− 8.58***
		Panel ADF-stat.	− 3.75	− 3.15***

***1% significance level

5 Empirical result

5.1 Panel unit root result

In Table 2, the study presents the panel unit root result for the heterogeneous process (Im et al. 2003) and the homogenous unit root tests (Breitung 2000; Levin et al. 2002). Table 2 shows clearly that for the panel, we accept the null hypothesis of unit root, at level. To this end, we first difference the data in the panel and observed that all the variables are stationary. It then implies that at the first difference, we can reject the null hypothesis of unit roots in the panel and accept the alternate hypothesis of no unit root. That is, the variables are non-stationary at levels but at first difference.

5.2 Panel cointegration result

Since it has been confirmed that all the variables employed in the study are stationary at first difference, instead of at levels, we then proceed to carry out the panel cointegration test given by Pedroni (1999). It is of high importance to be able to determine whether a long-run relationship exists between the explanatory variables and carbon emissions in BRICS. In doing this, four within-group tests and three between-group tests are explored

Table 4 Johansen fisher panel cointegration test

Hypothesised no. of CE(s)	Fisher stat. (trace test)	Fisher stat. (max-eigen test)
None	139.2***	83.57***
At most 1	80.46***	43.33***
At most 2	45.70***	29.57***
At most 3	25.78***	21.23**
At most 4	20.07**	20.07**

**, ***Stand for 5, 1% significance level, respectively

Table 5 Kao residual cointegration test

ADF	– 2.282***

***1% significance level

and presented in Table 3. In the table, there are two columns, namely the between-dimension and the within-dimension.

The between-dimension column presents the computed value of the statistics based on estimates that average individually estimated coefficients for every country in the panel, while the within-dimension column presents the computed value based on the estimates that pool the autoregressive coefficient across the different countries in the panel for the unit root tests on the estimated residuals. In Table 3, null hypothesis of no cointegration is rejected for both between-group and within-group dimensions. Only the group rho is statistically insignificant in the between-dimension and only the panel v statistic is insignificant in the within-dimension. Hence, we conclude that there is a long-run relationship between the variables.

In Table 4, the Johansen Fisher Panel cointegration test is presented to lend support to the result presented in Table 3. It was observed that all the equations are statistically, significant thereby encouraging us to reject the null hypothesis of no cointegration and accepting the alternative hypothesis that long-run relationship exists between the variables. The Kao residual cointegration test is also presented in Table 5, and the result gives credence to the conclusion in Tables 3 and 4 as the ADF statistic is also statistically significant.

To this end, we can safely conclude that electricity consumption, capital investment, economic growth and carbon emissions in Brazil, Russia, India, China and South Africa are cointegrated. This means that carbon emissions among the countries in the panel depend greatly on these explanatory variables in the long run. Having been able to establish this, the coefficients of the variables can now be estimated using the panel cointegration techniques of FMOLS and DOLS.

5.3 Panel cointegration estimates

The panel cointegration estimates employed in this study include the fully modified OLS (FMOLS) presented in Table 6 and the dynamic OLS (DOLS) presented in Table 7. In Table 6, we present the coefficients of electricity consumption per capita, real output per capita, capital investment and the interaction between capital investment and electricity consumption for the individual countries and for the panel.

Table 6 FMOLS result of CO_2 emission in BRICS

Variables	Brazil	Russia	India	China	South Africa	Panel
EC	0.457*	0.754***	0.676***	0.331**	0.277**	0.499***
GDPPC	4.929**	− 0.92*	3.581***	− 1.641	− 1.695**	0.851*
GDPPC^2	− 2.075	0.067***	− 0.62	0.104	0.158	− 0.473
CI	− 0.055***	0.048	0.029***	− 0.112**	− 0.114***	− 0.041***
ECI	0.846*	− 0.78***	− 1.992***	1.068***	0.349*	− 0.102**
C	− 14.562	7.062***	− 17.151	− 11.811	10.437	− 5.205*
R^2	0.924	0.791	0.988	0.991	0.917	
Adj. R^2	0.899	0.725	0.985	0.988	0.891	
Durbin–Watson	1.68	1.77	1.34	1.46	1.98	

***, ** and *1, 5 and 10% level of significance, respectively

Table 7 DOLS estimation result of CO_2 emission in BRICS

Variables	Brazil	Russia	India	China	South Africa	Panel
EC	0.527*	0.888***	0.575**	0.362**	− 0.141***	0.442***
GDPPC	3.161***	3.508*	1.297*	0.823*	5.545***	2.867**
GDPPC^2	− 1.849**	− 0.802***	− 0.851	− 0.145**	− 2.604*	− 1.25**
CI	0.004*	0.028**	0.096**	− 0.097***	− 0.083	− 0.01***
ECI	− 0.901*	− 0.554***	− 0.746***	0.736***	0.912*	− 0.111***
C	− 1.251***	− 5.529*	− 2.948	2.318**	− 9.673	− 3.417**
R^2	0.989	0.976	0.996	0.998	0.973	
Adj. R^2	0.958	0.906	0.988	0.968	0.892	
Durbin–Watson	1.77	2.20	1.62	2.19	2.15	

***, ** and *1, 5 and 10% level of significance, respectively; lead (0) and lag (1)

In Table 6, the FMOLS result indicates that electricity consumption and real GDP per capita positively and significantly impact carbon emission in BRICS, which conform to our a priori expectation since most of the electricity generated in these countries is from non-renewable sources. Capital investment and the interaction term between electricity consumption and investment negatively and significantly impact the level of emissions in BRICS. The reason for this is not far-fetched as these countries, unlike what obtains in other developing countries, have been able to step up their environmental laws and have therefore attracted specific amount of less pollution emitting industries. This positive scenario also robed off on the interaction term as electricity consumption works through investment channel in BRICS to lower the level of carbon emissions. For the panel, the EKC proposition holds in BRICS as suggested by the coefficients of the two real GDP per capita in the model. For the country-specific result, electricity consumption contributed positively and significantly to carbon emissions in Brazil, Russia, India and China, but contributed negatively to emission in South Africa. This may be attributed to the fact that Russia is one of the largest world producers of fossil fuels, Brazil's increase in deforestation in the Amazon rainforest for industrial expansion and settlement, China's reopening of coal reserves to generate more electricity, and India's energy sector that depends on 60% coal. Capital investment contributed positively to emissions in Russia and India but contributed negatively to Brazil, China and South Africa. The implication of this is that capital investment in Russia and India has not been environmentally friendly, while that of Brazil, China and South Africa has been to a large extent. The EKC hypothesis is also observed to hold in Brazil and India, but not in the other three countries.

In Table 7, the dynamic OLS result shows that for the panel of countries in BRICS, electricity consumption and growth positively and significantly contributed to the level of emissions in BRICS. This is in sync with the earlier result obtained in the FMOLS. Also, the negative sign of $GDPPC^2$ coupled with the positive sign of GDPPC implies that the environmental Kuznets curve proposition holds in BRICS using the dynamic OLS approach. Moreover, capital investment was observed to have negative impact on the level of emissions in the panel of countries in BRICS. Another key result is the analysis is the confirmation of the earlier result between the FMOLS and the DOLS that the interaction term between electricity consumption and investment negatively and significantly impacts carbon emissions in BRICS. This means that electricity can interact with investment to reverse the earlier increase in emissions caused by electricity consumption. It thus confirms the robustness of the approaches employed. It also means that capital investment plays a vital role in the interaction and has helped to abate emissions in BRICS. With country-specific results, Table 7 shows that except for South Africa, electricity consumption has positive effect on carbon emission in the remaining four countries. This result is quite understandable as South Africa only recently inaugurated wind farms made up of sixty turbines, which is among the largest in Africa to provide stable electricity for about 100,000 homes as part of its renewable energy project to assist independent producers of power (Philips, 2014). Similarly, the EKC was confirmed individually in Brazil, Russia, India, China and South Africa. However, capital investment positively enhanced emissions in Brazil, Russia and India, while it has negative impact on emissions in China and South Africa.

Having observed that capital investment in BRICS helps to abate the level of emission, it shows clearly that the pollution halo theory (Gray 2002; Copeland and Taylor 2004) is supported in these five countries. Since weak institutional control can reduce the anticipated gains in a region as suggested by Eregha and Mesagan (2016), it implies that efforts should be intensified in monitoring the industries that are domiciled in BRICS to ensure that they continue to employ technologies that are environment-friendly, and a carbon tax can even be imposed when necessary to ensure that the current environmental gains from capital investment are sustained. Moreover, the existence of the EKC in the panel implies that Brazil, Russia, India, China and South Africa can jointly find a way to determine the acceptable threshold level of output or growth beyond which carbon emission can begin to decline. Once this threshold is determined, they can then project to boost their real gross domestic output beyond the threshold to lower the level of emissions and improve their environmental quality.

6 Summary and conclusion

This study has beamed searchlight on the capital investment channel of environmental improvement in Brazil, Russia, India, China and South Africa. It covers the period of 1992 to 2014 based on the availability of data. In the study, several theories and studies were reviewed, and the methodology employed is the panel cointegration techniques of Pedroni (1999, 2000). The study sets out to critically examine the impact of electricity consumption on emissions in BRICS, to find out if carbon emission has been enhanced by capital investment in BRICS, to determine if capital investment can interact with electricity consumption to abate the amount of emission in BRICS and finally to test the existence of the environmental Kuznets curve (EKC) among the five countries. To this end, the study employed five variables of real GDP per capita, electricity consumption per capita, gross capital formation as a ratio of GDP to proxy capital investment, carbon emission (CO_2) and the interaction term between capital investment and electricity consumption. The unit root test conducted indicates that all the variables are stationary at first difference using the heterogeneous and homogeneous unit root processes, respectively. Also, three different criteria were used to test for the existence of long-run relationships among the variables; they include the Pedroni residual cointegration test, Johansen Fisher panel cointegration test and the Kao residual cointegration test. All the tests confirmed that long-run relationship exists among the variables, thereby suggesting that carbon emissions in BRICS have some level of dependence on the selected explanatory variables. To achieve the first objective, both the FMOLS and DOLS results showed clearly that electricity consumption positively and significantly enhanced carbon emission in BRICS. For the second objective, both methods confirmed that capital investment helps to abate carbon emission in BRICS. For the third objective, it was confirmed that capital investment interacted with electricity consumption to abate the level of emissions in BRICS. The last objective was clearly achieved as the EKC hypothesis was confirmed for the panel of countries in BRICS in both approaches employed.

To this end, the central conclusion drawn in this study is that that capital investment is an important channel for improving environmental quality over time. The theoretic contribution is in terms of confirming the EKC hypothesis in BRICS. Also, the methodology makes it possible to determine the specific situation in each country since we recognised that the countries differ from each other and require individually designed approaches rather than a group strategy. In South Africa for instance, electricity consumption and investment negatively impact its environment. The country's efforts to establish wind farms with several turbines may be partly responsible for this. However, whether this can be sustained in the long term is another question. As noted in CAT (2017), South Africa is very close to achieving its 2030 emissions reduction target, but the country's coal-powering plant that supplies about 93% of its electricity is expected to grow due to the construction of new coal plants and the uncertainty regarding the date to start implementing its planned carbon tax. To sustain the present tempo, South Africa must standardise its environmental regulations to attract and keep only clean investments and must consistently maintain its set agreement under the Copenhagen Accord[6] that emissions be reduced below the business-as-usual (BaU) levels. For Brazil, the country has made efforts at strengthening its biofuel production and its generation of electricity from non-renewables is highest in BRICS. However, since its electricity consumption, output growth, and capital investment hampered its environmental quality in this study, the country's high pace of deforestation in the Amazon rainforest to increase arable lands for agriculture and settlement is partly responsible. Also, Brazil's budget cut of 50% to the Ministry of Environment, due to the current economic recession, will have a debilitating impact on its quest to lower climate change and meet the Paris Agreement set target. Brazil needs to strengthen its environmental policy by increasing budget to its Environment Ministry to adequately monitor

[6] Copenhagen Accord provided a document drafted by the USA and agreed on by other 140 countries. In the Accord, emissions reduction targets for 2020 were set and mitigation actions were also arrived at for developing countries.

deforestation, reverse its plans to increase fossil fuel energy and increase mitigation efforts in other sectors of the economy.

In India, electricity consumption, output growth and investment lowered environmental quality, whereas the interaction term enhanced its environmental quality. The country's efforts to permit the sale of only electric and battery-driven vehicles from 2030 are a right step. However, the country needs to consider the full implementation of its proposed draft electricity plan and increase its non-fossil fuel energy generation beyond the 40% currently proposed for 2030. This will provide the needed impetus for electricity consumption and investment to abate emissions. For China, the firing and reopening of coal reserves explained why electricity consumption and growth fuelled CO_2 emissions in this study. Also, as noted by CAT (2017), China's current national effort is far below what is required to keep global warming below 1.5 and even 2 °C of the Paris Agreement. Therefore, the country needs to do more in diversifying its industrial energy use into renewable energy since its industrial sector accounts for over 50% of its final energy consumed. Lastly, electricity consumption, growth and investment increased emissions in Russia. This is expected since the country is one of the world's largest fossil fuel producers and emitters too (CAT 2017). However, interacting with electricity consumption, capital investment can provide a good channel to improve environment for Russia. Hence, the country needs to quickly ratify the Paris Agreement as against plan to delay ratification till 2019. The INDC in Russia should also set a very strong emissions reductions target, and the government should put in place policies aimed at strengthening renewable energy production. In general, capital investment has been confirmed as an important channel to improve the quality of BRICS environment; hence, it should be well monitored to provide such anticipated gains. However, for further studies, it will be interesting to delve into the role of public policy in attracting clean technologies for improving environmental quality.

References

Akpan, G. E., & Akpan, U. F. (2012). Electricity consumption, carbon emissions and economic growth in Nigeria. *International Journal of Energy Economics, 2*(4), 292–306.

Al-mulali, U. (2011). Oil consumption, CO_2 emission and economic growth in MENA countries. *Energy, 36*(10), 6165–6171.

Andreoni, J., & Levinson, A. (2001). The simple analytics of the environmental Kuznets curve. *Journal of Public Economics, 80*(2), 269–286.

Apergis, N., Payne, J. E., Menyah, K., & Wolde-Rufael, Y. (2010). On the causal relationship between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics, 69,* 2255–2260.

Bangake, C., & Eggoh, J. C. (2011). The Feldstein-Horioka puzzle in African countries: A panel cointegration analysis. *Economic Modelling, 28,* 939–947.

Baumol, W. J., & Oates, W. E. (1988). *The theory of environmental policy*. Cambridge: Cambridge University Press.

Bento, J. P. C., & Moutinho, V. (2016). CO_2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy. *Renewable and Sustainable Energy Reviews, 55,* 42–155.

Bernard, J., Clavet, F., & Ondo, J. (2004). Electricity production and CO_2 emission reduction: Dancing to a different tune across the Canada–Us border. *Canadian Public Policy, 30*(4), 401–426.

Blomquist, G. C., & Cave, L. A. (2008). Environmental policy in the European Union: Fostering the development of pollution havens? *Ecological Economics, 65,* 253–261.

BP Statistical Review of World Energy. (2017). Data on world energy by countries and regions. http://www.bp.com/statisticalreview. Accessed December 17, 2017.

Breitung J. (2000). The local power of some unit root tests for panel data. In: Baltagi, B. (Ed.), *Nonstationary panels, panel cointegration, and dynamic panels*. *Advances in Econometrics*, 15, 161–178.

Chaturvedi, V., Clarke, L., Edmonds, J., Calvin, K., & Kyle, P. (2014). Capital investment requirements for greenhouse gas emissions mitigation in power generation on near term to century time scales and global to regional spatial scales. *Energy Economics, 46,* 267–278.

Chichinisky, G. (1994). North-south trade and the global environment. *American Economic Review, 84*(4), 851–874.

Cho, S., Tanaka, K., Wu, J., Robert, R. K., & Kim, T. (2016). Effects of nuclear power plant shutdowns on electricity consumption and greenhouse gas emissions after the Tohoku Earthquake. *Energy Economics*. https://doi.org/10.1016/j.eneco.2016.01.014.

Chung, S. (2014). Environmental regulation and foreign direct investment: Evidence from South Korea. *Journal of Development Economics, 108,* 222–236.

Climate Action Tracker. (2017). Climates analytics for countries. www.climateactiontracker.org/countries.html. Accessed December 18, 2017.

Cole, M. A. (2004). Trade, the pollution haven hypothesis and the environmental kuznets curve: Examining the linkages. *Ecological Economics, 48*(1), 71–81.

Cole, M., & Elliott, R. (2005). FDI and the capital intensity of "Dirty" sectors: A missing piece of the pollution haven puzzle. *Review of Development Economics, 9,* 530–548.

Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature, 42*(1), 7–71.

Cowan, W. N., Chang, T., Inglesi-Lotz, R., & Gupta, R. (2014). The nexus of electricity consumption, economic growth and CO_2 emissions in the BRICS countries. *Energy Policy, 66,* 359–368.

Dasgupta, S., Laplante, B., Wang, H., & Wheeler, D. (2002). Confronting the environmental Kuznets curve. *Journal of Economic Perspectives, 16*(1), 147–168.

Deviren, S. A., & Deviren, B. (2016). The relationship between carbon dioxide emission and economic growth: Hierarchical structure methods. *Physica A, 451,* 429–439.

Dogan, E., & Seker, F. (2016). The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. *Renewable and Sustainable Energy Reviews, 60,* 1074–1085.

Eregha, P. B., & Mesagan, E. P. (2016). Oil resource abundance, institutions and growth: Evidence from oil producing African countries. *Journal of Policy Modeling, 38*(3), 603–619.

Eregha, P., & Mesagan, E. (2017). Energy consumption, oil price and macroeconomic performance in energy dependent African countries. *Applied Econometrics, 46,* 74–89.

Eregha, P. B., & Nwokoma, N. I. (2014). FDI and the environment: Evidence from the fully modified and dynamic OLS approaches in WAMZ. *West African Financial and Economic Review, 11*(1), 81–94.

Eskeland, G. S., & Harrison, A. E. (2003). Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of Development Economics, 70*(1), 1–23.

Farhani, S., & Ben Rejeb, J. (2012). Energy consumption, economic growth and CO_2 emissions: Evidence from panel data for MENA region. *International Journal of Energy Economics and Policy, 2*(2), 71–81.

Farhani, S., & Shahbaz, M. (2014). What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO_2 emissions in MENA region? *Renewable and Sustainable Energy Reviews, 40,* 80–90.

Gray, K. R. (2002). Foreign direct investment and environmental impacts-is the debate over? *RECIEL, 11*(3), 306–316.

Greaker, M. (2007). Strategic environmental policy, eco-dumping or a green strategy. *Journal of Environmental Economics and Management, 45,* 692–707.

Grubb, M., Sha, F., Spencer, T., Hughes, N., Zhang, Z., & Agnolucci, P. (2015). A review of chinese CO_2 emission projections to 2030: The role of economic structure and policy. *Climate Policy, 15*(sup1), S7–S39.

He, J. (2006). Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emission of sulfur dioxide (SO_2) in Chinese provinces. *Ecological Economics, 60,* 228–245.

Im, K. S., Pesaran, M. H., & Shin, Y. C. (2003). Testing for units roots in heterogeneous panels. *Journal of Econometrics, 115,* 53–74.

Jung, Y. (1996). Scenarios of future energy demand and carbon dioxide emissions in the Republic of Korea. *Royal Swedish Academy of Sciences, 25*(4), 258–262.

Lean, H. H., & Smyth, R. (2010). CO_2 emissions, electricity consumption and output in ASEAN. *Applied Energy, 87*(6), 1858–1864.

Letchumanan, R., & Kodama, F. (2000). Reconciling the conflict between the 'pollution-haven' hypothesis and an emerging trajectory of international technology transfer. *Research Policy, 29,* 59–79.

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics, 108,* 1–24.

Li, F., Dong, S., Li, X., Liang, Q., & Yang, W. (2011). Energy consumption-economic growth relationship and carbon dioxide emissions in China. *Energy Policy, 39,* 568–574.

Masiero, G. (2011). Developments of biofuels in Brazil and East Asia: Experiences and challenges. *Revista Brasileira de Política Internacional, 54*(2), 97–117.

Mazumdaru, S. (2017). Climate change—India battles to balance economy and environment. http://p.dw.com/p/2mxvR. Accessed December 18, 2017.

Menyah, K., & Wolde-Rufael, Y. (2010). Energy consumption, pollutant emissions and economic growth in South Africa. *Energy Economics, 32,* 1374–1382.

Mesagan, E. P. (2015a). Carbon emission and economic growth in Nigeria. *The IUP Journal of Applied Economics, 14*(4), 61–75.

Mesagan, E. P. (2015b). Economic growth and environment nexus: The role of foreign direct investment. *A Research Journal on Contemporary Issues and Development, Rivers State University of Education, 4*(3), 44–52.

Morazan, P., Knoke, I., Knoblauch, D., & Schafer, T. (2012). The role of BRICS in the developing world. *Directorate-General for External Policies, European Parliament,* EXPO/B/DEVE/FWC/2009/01/Lot5/24.

Narayan, P. K., Saboori, B., & Soleymani, A. (2016). Economic growth and carbon emissions. *Economic Modelling, 53,* 388–397.

Nilsson, A., Stoll, P., & Brandt, N. (2015). *Assessing the impact of real-time price visualization on residential electricity consumption, costs, and carbon emissions*. Resour: Conservation and Recy. https://doi.org/10.1016/j.resconrec.2015.10.007.

Ozturk, I., & Uddin, G. S. (2012). Causality among carbon emissions, energy consumption and growth in India. *Economic Research, 3,* 752–775.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics, 61,* 653–670.

Pedroni, P. (2000). Fully modified OLS for heterogeneous cointegrated panels. *Advances in Econometrics, 15,* 93–130.

Philips, A. (2014). In lead up to carbon price, South Africa preps carbon offset program. *Climate*. http://thinkprogress.org/climate/2014/07/14/3459903/south-africa-carbon. Accessed May 13, 2016.

Safdari, M., Barghandan, A., & Shaikhi, A. M. (2013). Has CO_2 emission increased the iranian economic growth? *International Journal of Academic Research in Business and Social Sciences, 3*(1), 314–352.

Salahuddin, M., Gow, J., & Ozturk, I. (2015). Is the long-run relationship between economic growth, electricity consumption, carbon-dioxide emissions and financial development in gulf cooperation council countries robust? *Renewable and Sustainable Energy Reviews, 51,* 317–326.

Seetanah, B., & Vinesh, S. (2012). On the relationship between CO_2 emissions and economic growth: The mauritian experience. http://www.csae.ox.ac.uk/conferences/2011-edia/papers/776-Seetanah.pdf. Assessed March 20, 2016.

Sims, R. E., Rogner, H. H., & Gregory, K. (2003). Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. *Energy Policy, 31*(13), 1315–1326.

Stern, D. I. (2003). The environmental Kuznets curve. In *International society for ecological economics internet encyclopaedia of ecological economics*. Department of Economics, Rensselaer Polytechnic Institute, Troy, NY 12180, USA.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World Development, 32*(8), 1419–1439.

Tang, C. F., & Tan, B. W. (2015). The impact of energy consumption, income and foreign direct investment on carbon-dioxide emissions in Vietnam. *Energy, 79,* 447–454.

Temurshoev, U. (2006). Pollution haven hypothesis or factor endowment hypothesis: The theory and empirical examination for the US and China. Working Paper Series 292, CERGE-EI, Prague.

Tiwari, A. K. (2012). On the dynamics of energy consumption, CO_2 emissions and economic growth: Evidence from India. *Indian Economic Review, 47*(1), 57–87.

Wilson, R. (2014). America versus China: The new reality of global energy. www.theenergycollective.com/robertwilson190/380971/america-versus-china-what-difference-decade-makes. Accessed December 18, 2017.

World Development Indicators. (2017). The World Bank Databank. http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators. Accessed August 21, 2017.

Zhang, X. P., & Cheng, X. M. (2009). Energy consumption, carbon emissions, and economic growth in China. *Ecological Economics, 68,* 2706–2712.

Zhang, C., & Zhou, X. (2016). Does foreign direct investment lead to lower CO_2 emissions? Evidence from a regional analysis in China. *Renewable and Sustainable Energy Reviews, 58,* 943–951.

Zhou, N., Fridley, D., McNeil, M., Zheng, N., Ke, J., & Levine, M. (2011). *China's energy and carbon emissions outlook to 2050* (No. LBNL-4472E). Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA (US).