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Modelling coal rent, economic growth and CO_2 emissions: Does regulatory quality matter in BRICS economies?

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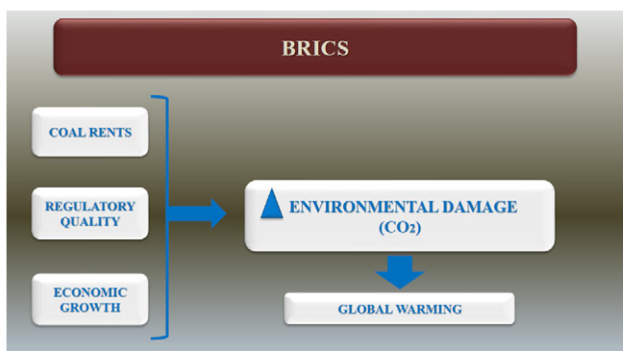
HIGHLIGHTS

- BRICS economies were investigated on coal rent, economic growth and CO_2 emissions.
- Unlike coal consumption, an increase in coal rents does not increase CO_2 emissions in BRICS countries.
- Energy diversification in BRICS economies can abate global dwindling energy market.
- Environmental sustainability is achieved by decoupling CO_2 from GDP in BRICS economies.

GRAPHICAL ABSTRACT



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ABSTRACT

Global warming issues have been on the front burner of most economies and Brazil, Russia, India, China and South Africa countries (BRICS) are no exception. The region has joined the rest of the world on the global strides to mitigate against global warming in terms of decoupling carbon dioxide emissions from economic growth. This is the motivation for the present study to consider the interaction between economic growth, pollutant emissions, coal rent while accounting for the role of other covariates like regulatory quality. The study is conducted in a balanced panel setting over annual frequency data from 1990 to 2014. To this end, Pooled mean group with dynamic autoregressive distributed lag [PMG-ARDL (1,1,1,1,1)] was conducted to explore the coal-rents-energy nexus. The empirical study shows that for BRICS countries, unlike coal consumption, coal rents have a significant but negative impact on CO_2 emissions. Also, in contrast to expectation, regulations on coal rents in form of carbon damage costs have a significant but positive impact on CO_2 emissions. This suggest that in line with the drive for growth by BRICS countries, and to achieve a reduction in the levels of CO_2 emissions for green growth and sustainable development, more stringent environmental-energy-related regulations are inevitable. Thus, for policymakers it is vital to reinforce the use of stringent regulations as these economies opens up to more use of coal energy. However, the need to shift, the energy mix in BRICS to renewables is pertinent in a time of global environmental consciousness for cleaner energy sources and environmentally friendly ecosystem.
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1. Introduction

The prevalence of CO_2 emissions harms the global climate, resulting in climate change. Historically, to every viable state, energy supply and consumption is pivotal to socio-economic growth which resultantly brings sustainable development. In every sense of the word, development is a hallmark of growing economies. Economies such as Brazil, Russia, India, China and South Africa (BRICS) Countries inclusive of many other countries being signatories to the Kyoto Protocol; acknowledge that "climate change is one of the greatest challenges and threats towards achieving green growth and sustainable development". This committal alliance comes with pledges to reduce Greenhouse gas emissions (GHGs) by 2020 as outlined by the Intergovernmental Panel on Climate Change (IPCC, 2013).

The 21st session of the United Nations Conference of the Parties (COP21) held in Paris in December 2015 was a major milestone in the struggle to minimize pollution and CO_2 emissions and to mitigate adverse climate change and global warming (Esso and Keho, 2016). Subsequent COP24 built on the layout template of predefined goals. For instance, South Africa has pledged to reduce GHG emissions to 34% by 2020, but the trivial effort had been made to construct coal-fired power plants, including the Medupi Power Plant which was funded by the African Development Bank, World Bank and other financial institutions. The appreciation of BRICS GDP has enlarged the archives of literature on the effect of unhealthy gas emissions. It is noteworthy to highlight however that regulatory operation of these emissions is governed by extant viable policies, but proactive enforcement remains a tag question. In line with this, BRICS countries signed a "multilateral agreement on climate co-operation and the green economy" during the 5th BRICS Summit in 2013, which ensures the exchange of technical and financial support to combat the negative impact of climate change on developing countries, Cowan et al. (2014). Such agreement accommodates the 2030 Agenda for Sustainable Development.

Literature is replete with the nature of causal links between energy consumption and economic growth on countries such as BRIC, BRICS, OECD and Sub-Saharan African Countries (Solarin and Shahbaz, 2013; Solarin and Shahbaz, 2015; Bekun et al., 2019a; Bekun et al., 2019b). It is indicated that there is the existence of both bi-directional and unidirectional relationships between energy consumption and economic growth, hence, consumption of energy deteriorates the environment (Yoo, 2006a;Yoo, 2006b; Akinlo, 2008; Odhiambo, 2010; Apergis and Payne, 2010; Cowan et al., 2014). The contribution of these studies revealed that the environment could be depleted by mere consumption of energy which ordinarily raises a point of concerns among scholars.

BRICS countries[1] are heavily dependent on energy-intensive sectors such as construction, mining and manufacturing for respective levels of economic growth and industrialization as would many countries around the world faced with a rapid increase in population, lifestyle changes and urbanization. Development of such feature creates incremental energy consumption demand, posing serious climate change and global warming concerns. The combination of energy demand and international pressures on climate change and global warming are raising concerns about how countries would achieve Green Growth and Sustainable Development. International concerns over the ability of energy supply to keep up with energy demand and increasing levels of carbon dioxide (CO_2) emissions that are associated with global warming and climate change, is a serious challenge in respect to economic, energy, social inclusiveness as well as environmental sustainability policies. Therefore, these concerns call for the sustained attention of policymakers to better explore the causal links between energy consumption, economic growth and CO_2 emissions. Tripartite environmental indices as these should synchronise by default not create risks to health.

Another interesting theme involves the way energy is sourced, generated and consumed resulting to major environmental shortcomings and social well-being such as pollution, greenhouse gases (GHGs), carbon dioxide (CO_2) emissions; which is indicated that coal energy trailed by oil and natural gas rank the highest (IPCC, 2013). Energy consumption drawbacks (coal) emanate mostly from energy fossil oils sources which significantly impact CO_2 emissions and subsequently green growth and sustainable development. According to Ben Amar (2013), energy is a critical input to economic development and an essential part of human activity, as consumption of energy is significant to improving social conditions, but the use of energy has substantial social and environmental implications in addition to impacts on the supply chain. Whereas the need for social-economic transformation remains a key driver of political strategy in many countries around the world, the threat for global warming and climate change continue to raise international pressures. It is imperative that the need to further examine the relationship between economic growth, energy consumption and carbon dioxide (CO_2) emissions, with special emphasis on coal consumption.

Coal consumption is crucial to measuring economic success within the context of this study. BRICS countries, like other coal-dependent countries, have abundant coal endowments that could probably meet their current and future energy needs for economic growth and sustainable development. Figs. 2 to 5 show coal resources (Fig. 1), coal production in million tons (Fig. 2), coal consumption in million tons (Fig. 3) and carbon dioxide CO2 emissions (Fig. 4) for the BRICS countries for the period 1990–2015 which demonstrate BRICS countries' current dependence on coal as their key source of energy for economic growth and to subsequently achieve sustainable development. (See Figs. 6 and 7.)

The high dependence on coal consumption by the BRICS countries (Rodionova et al., 2017) and much other coal consumption dependent countries and the resulting high levels of CO_2 emissions necessitate an understanding of the relationship between coal rents and sustainable development. Coal rents, which is resource rent from coal production provides incentives to coal exploration companies to utilize coal for energy consumption (Arnason, 2008; Mehrara and Baghbanpour, 2015). It is not covert that coal production is majorly utilized for energy consumption. The literature revealed that coal rents represent a large part of GDP contributions in BRICS economies. Like any other natural resources; such as oil rents, coal rents play a critical part in the economy of the developed and developing countries and it is crucial to show how natural resources may affect sustainable development. Extant studies have emerged because of the versatile nature of coal (Menyah and Wolde-Rufael, 2010; Park and Hoon, 2013; Lin and Wesseh, 2014) to examine the degree of association that exists between energy or coal consumption, economic growth and carbon dioxide (CO2) emissions.

Coal continues to be the dominant energy source for developing economies. The adverse consequence of such energy consumption has generated condemnation from United Nations International agencies and pressure groups. It resulted in countries making commitments to curb the level of carbon dioxide emissions. However, the energy, environment and social policies of developing countries are at crossroads as policymakers are finding it difficult to strike a balance between economic development, environmental sustainability and social sustainability, as they move towards green growth and the sustainable development agenda. Considering the confirmed existence of causality between economic growth, energy consumption and carbon dioxide (CO2) emissions, there need to further explore ways in which countries can transit to green growth and sustainable development. Giving the foregoing, this study fills up an existing gap which assists stakeholders to find out how coal rents (the difference between the value of both hard and soft coal production at world prices and their total costs of production) affect the levels of CO2 emissions in BRICS.

[1] BRICS Countries: Association of five major emerging national economies: Brazil, Russia, India, China and South Africa, that are all leading developing or newly industrialized countries, but they are distinguished by their large, often fast-growing economies and significant influence on regional affairs; all five are G-20 members.

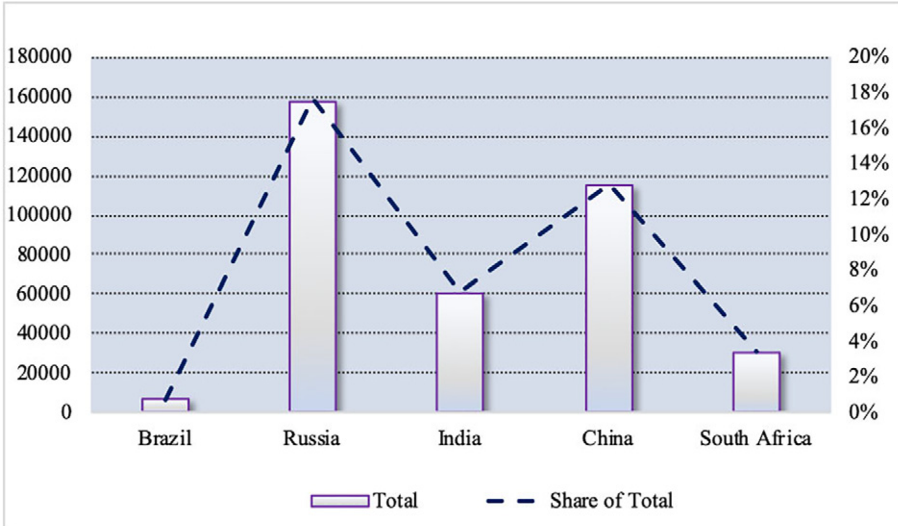

Fig. 1. Coal reserves in BRICS countries.

The choice of the BRICS countries is an interesting case study for this study given that CO2 emissions and sustainable development are a major ongoing concern for policymakers and energy environmentalist. Energy consumption is a fundamental element in economic development. It is estimated that >70% of the energy demand for the population and industries within BRICS countries and other countries around the world depend heavily on coal consumption. Numerous studies have examined the causality between economic growth and energy consumption, including other additional variables, but there are no studies that have focused on BRICS countries in respect to the variables of coal rents and CO2 emissions.

Although, the literature has studies on growth-energy-emissions nexus well documented, yet, there is a dearth of literature on coal energy in the case of BRICS countries. This study differs from previous studies that investigated determinants of emissions (Zakarya et al., 2015) or other forms of energy such as electricity (Cowan et al., 2014) in BRICS countries. Specifically, the current study contributes to the energy-emissions-growth debate by examining coal rents and its relationship with pollutant emissions (CO_2). We also investigate how this relationship is moderated by regulatory quality in the BRICS panel of countries, using data from 1990 to 2014 and focusing on panel-specific analysis. In summary, this study examined how coal rents, coal energy output, renewable and nuclear energy outputs relate with CO_2 emissions and how regulations moderate this relationship.

The remaining part of the research study is organized as follows. Section 2 presents a theoretical framework and a detailed empirical literature review. Thereafter, data and methodology used in this research are presented in Section 3, followed by the presentation of the research results and subsequent discussions in Section 4. Lastly, Section 5 presents the summary and conclusions, whereby the policy recommendations for future consideration by the governments of each of the BRICS and Panel of other selected countries are outlined.

2. Literature review

To achieve the aim of this study, the relationship between energy consumption, economic growth and CO2 emissions is presented in Fig. 10. The reason for this is to consider the endowments of natural

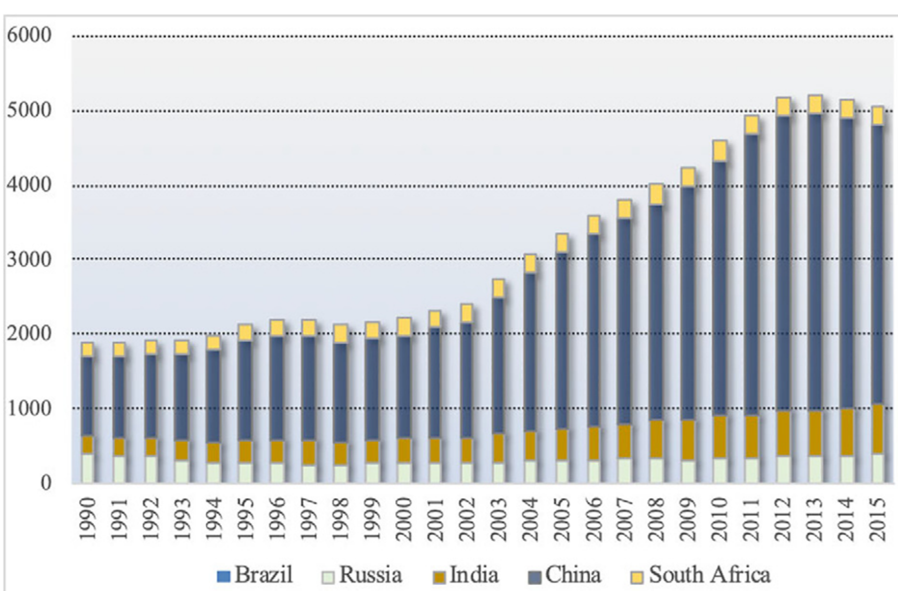

Fig. 2. Coal production (in million tonnes) in BRICS countries (1990–2015).

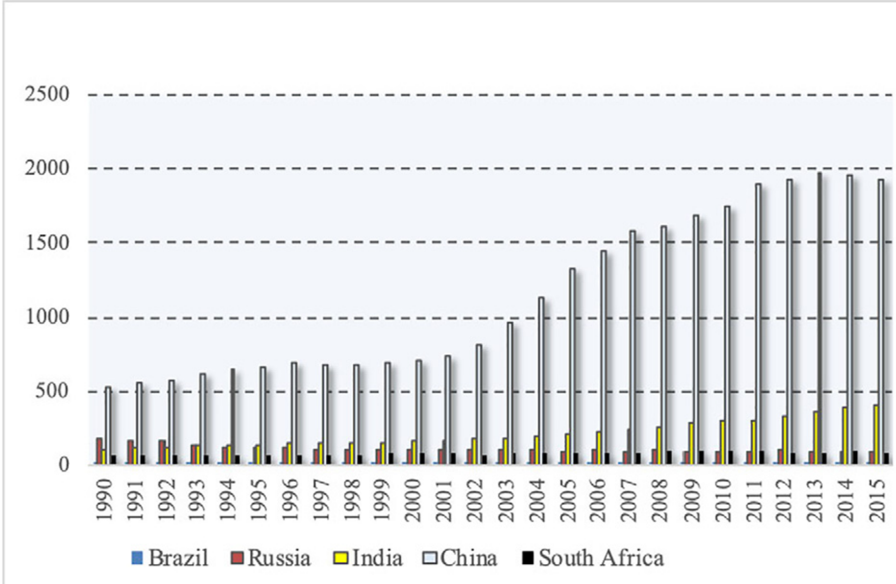

Fig. 3. Coal consumption (in million tonnes) in BRICS countries (1990–2015).

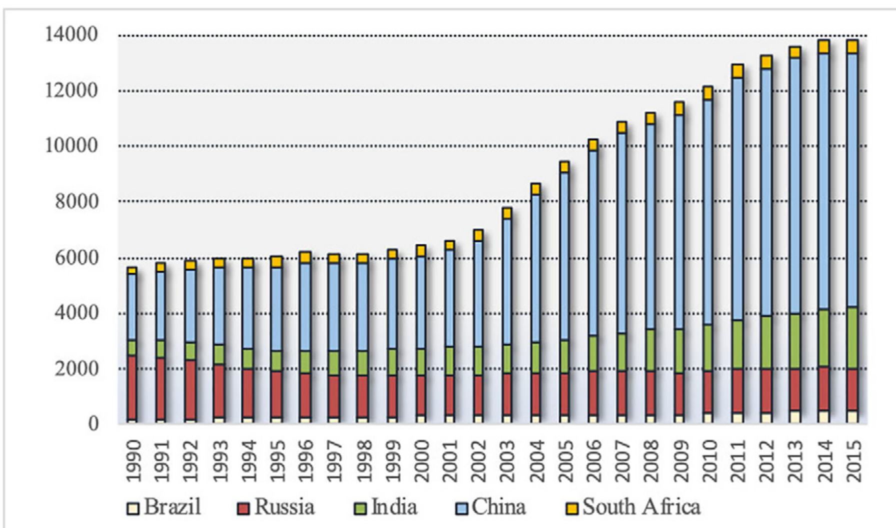

Fig. 4. CO_2 emissions (in million tonnes) in BRICS countries (1990–2015).

resources which through economic rents contributes to economic growth. The natural resources endowments are related to fossil fuels (coal), which results in coal rents and thus provide incentives for extraction towards coal consumption. Whereas the incentives from coal rents add value to economic growth, through an increase in coal production for coal energy output and exports of coal to the world commodity markets, this good intention has unintended consequences.

The increase in energy use often leads to high levels of CO_2 emissions (scale effect[2]), which are associated with climate change and global warming. In turn, there are drawbacks to the overall objective of sustainable development, which requires a balance between economic development, social inclusion and environmental sustainability (composition and technical effect). To minimize the effects of energy consumption to levels of CO_2 emissions without compromising economic growth, the study aims to assess the exploitation of other renewable energy and nuclear energy sources, coupled with additional regulations in addition to carbon damage costs, so as to infer on potentials for attaining green growth and sustainable development.

Energy generation systems tend to generate extensive and severe environmental and social hazards in the process of delivering energy for consumption. In essence, energy generated is often from dirty sources and therefore not Clean Energy,[3] whereby the costs of environmental and social degradation are minimized while accelerating economic growth. The generation of clean energy leads to positive externalities

[2] scale effect is the reduction in per-unit cost as the level of production increases. In this case, a higher volume of emissions is attributable to higher GDP per kilogram of oil equivalent of energy use

[3] Clean Energy: Is a form of power (Electricity) generation in which the cost of environmental and social degradation is minimized while accelerating economic growth for sustainable development

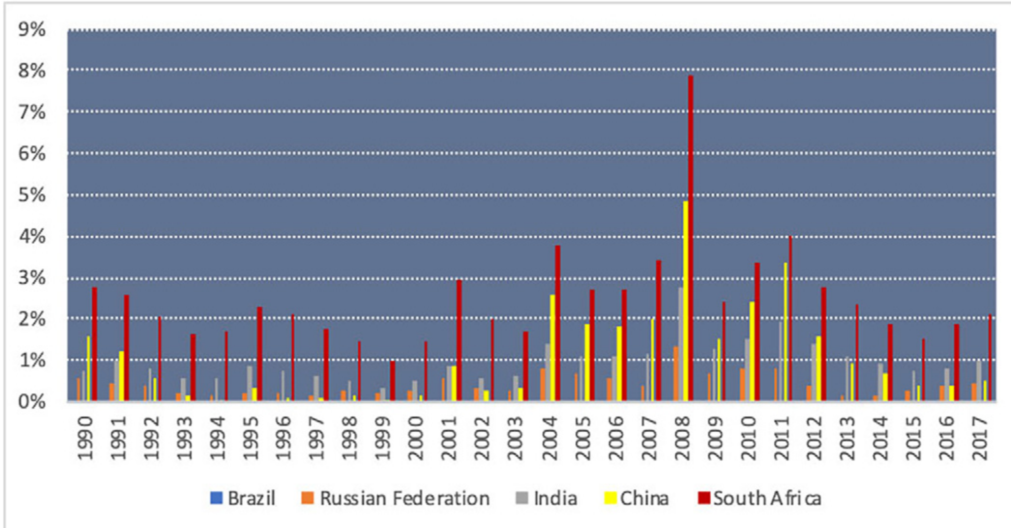

Fig. 5. Coal rents (% of GDP) in BRICS countries: 1970–2017.

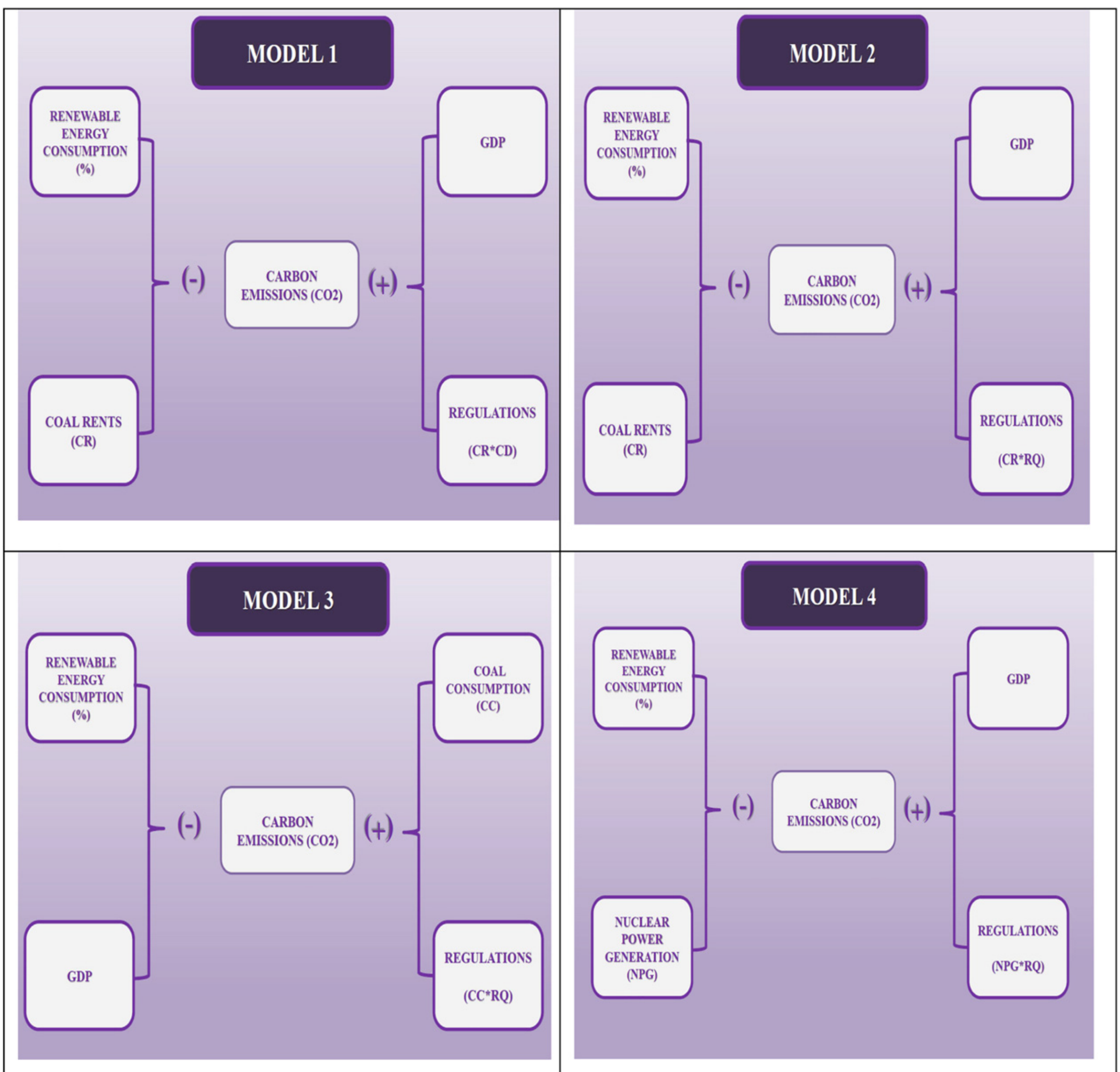

Fig. 8. Empirical scheme (based on PMG-ARDL).

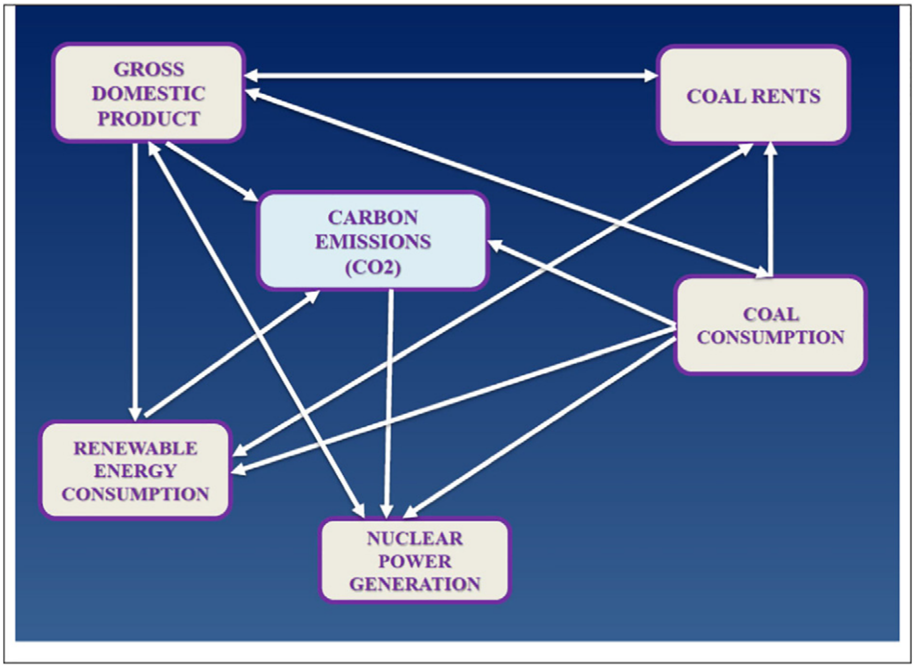

Fig. 9. Causality scheme.

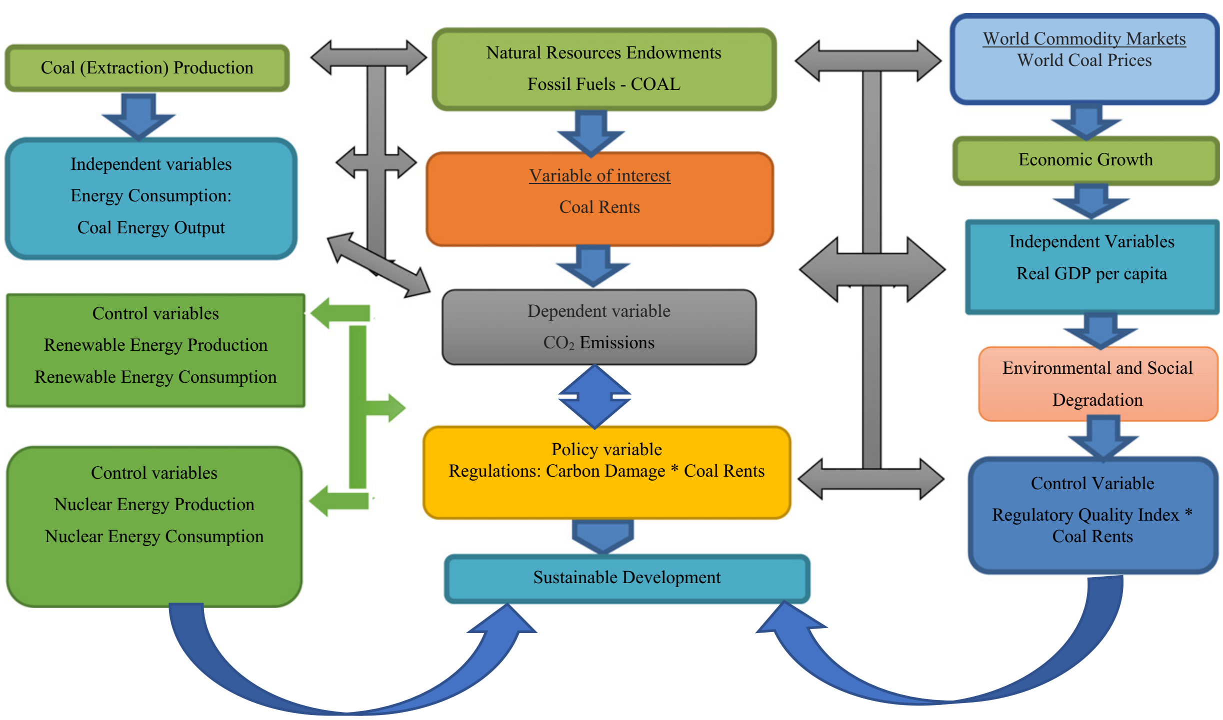

Fig. 10. Theoretic framework.

related to green growth[4] and sustainable development,[5] thereby reducing the effects of pollution and greenhouse gasses (GHG). The effects to environmental and social degradation like pollution, carbon dioxide (CO2) emissions, GHG and global warming have been associated with non-renewable energy,[6] such as fossil fuels, coal, petroleum, and natural gas.

On the other hand, power generation with little or no significant consequences to climate change and thus not harmful to the

[4] Green Growth: Describes an economic growth strategy that uses natural resources for economic development in a sustainable manner, reducing greenhouse gases (GHGs) and thereby achieving sustainable development for all.

[5] Sustainable Development: Economic growth or development that considers the environment and improves social well-being of all people, thereby creating opportunities for future generations.

[6] Non-Renewable Energy: Energy that is generated from resources that will run-out or will not be replenished in a lifetime

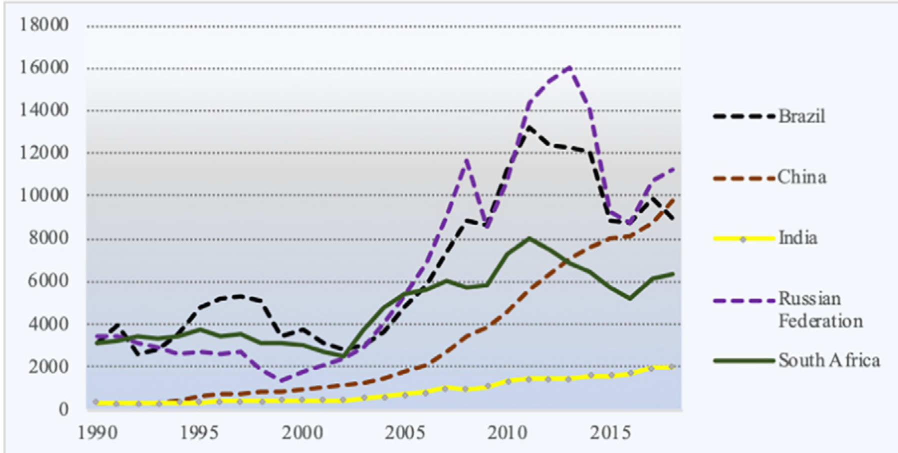

Fig. 6. GDP per capita (current US$) in BRICS countries: 1990–2018.

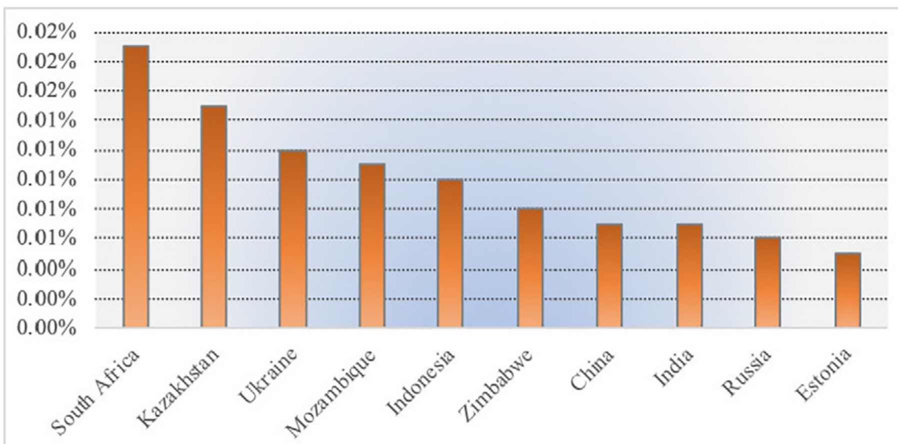

Fig. 7. Countries earning the most in coal rents relative to GDP (2015).

environment and social wellbeing has been associated with renewable energy[7] sources such as hydro, nuclear power, wind and solar. Since coal is an important and abundant energy resource for many countries, the challenge is how to use it to generate clean energy. Therefore, the generation of clean energy, while interlinking the economic, social and environmental challenges is critical for BRICS countries, including other countries around the world for attaining green growth and sustainable development.

Literature contains findings from energy and environment-related studies on causal links between economic growth, energy consumption and carbon dioxide (CO2) emissions with emphasis on research on BRICS (See Table 1). Thus, in what follows, we present what exists in the literature. We find that although most studies identify directions of causality in terms of total energy sources, the role of coal energy in the BRICS countries is under-researched.

2.1. Coal consumption and economic growth

In emphasizing the important inputs of coal energy to economic growth, researchers have studied the causal links between economic growth and coal consumption in few single-country case studies with variation in their direction of causality. In South Africa, for example, Odhiambo (2016) found a unidirectional (One-way) causal relationship flowing from coal consumption to employment, as well as a bidirectional causal link between employment and economic growth. Similarly, the existence of a bi-directional relationship flowing from coal consumption to economic growth, and coal consumption in Korea had an overall increase of over 3.9% per year, Yoo (2006a, 2006b).

Although, a unidirectional relationship exists running from GDP to coal consumption for China, and a similar one-way directional causal relationship running from coal consumption to GDP was for India (Li and Li, 2011), Apergis and Payne (2010) showed that the causal relationship between economic growth and coal consumption could be negative in the short-run and bi-directional. On the same pedestal, the study of Wassung (2010) on Water-Energy Nexus in South Africa explained that generation of energy requires high quantities of fresh water for cooling, and that the difficulty is likely to be additionally aggravated as more thermal power stations may be built to meet the intense increase in demand for energy in South Africa.

2.2. Economic growth and CO2 emissions

Over the past decades, scholars in the fields of economics and environment had been tasked with the concerns to increase growth in economies and improve on social degradation, as a consequence to carbon dioxide (CO_2) emissions from economic growth, which are considered the main cause of global warming and climate change. This enigma has seen several studies undertaken mainly to investigate the causal relationship between economic growth and CO2 emissions, and to test the Hypothesis for Environment Kuznets Curve (EKC), and thereby

[7] Renewable Energy: Energy that is generated from sources of nature that can be resourced and replenished on a human timescale, such as geothermal heat, sunlight, waves, wind, rain, and tides.

Table 1
Summary of findings from literature reviewed on economic growth, energy consumption, and CO_2 emissions for green growth and sustainable development.

No.	Author (s)	Period	Variables	Country (s)	Methodology	Results
1.	Akinlo (2008)	1980–2003	GDP and EC	11 Sub-Sahara Africa	ARDL Bounds and VECM	GDP ↔ EC
2.	Odhiambo (2009)	1971–2006	GDP and EC	South Africa	Co-Integration and VECM	GDP ↔ EC
3.	Odhiambo (2010)	1972–2008	GDP and EC	3 Sub-Sahara Africa	ARDL Bounds Testing	EC → GDP (RSA/KE) EC ↔ GDP (DRC)
4.	Yoo (2006a)	1971–2002	GDP and EC	ASEAN Countries	Johansen-Juselius Model Co-Integration Model	EC ↔ GDP (SGP & ML) GDP → EC (THL & IDN)
5.	Wolde-Rufael (2009)	1971–2004	GDP and EC	17 African Countries	Granger Causality Test	EC → GDP
6.	Odhiambo (2016)	1980–2012	GDP and CC	South Africa	ARDL Bounds Testing	CC → EMP EG ↔ EMP
7.	Yoo (2006b)	1968–2002	GDP and CC	South Korea	Co-Integration and Ganger	CC ↔ GDP
8.	Li and Li (2011)	1965–2006	GDP and CC	India & China	Co-Integration and Ganger	GDP → CC (China) CC → GDP (India)
9.	Apergis and Payne (2010)	1980–2005	GDP and CC	25 OECD Countries	Co-Integration/VECM	CC ↔ GDP
10.	Odhiambo (2012)	1970–2007	GDP and CO2	South Africa	ARDL Bounds Testing	GDP → CO2
11.	Dinda (2009)	1960–1990	GDP and CO2	OECD/Non–OECD	Ganger causality test	GDP → CO2
12.	Richmond and Kaufmann (2006)	1973–1997	GDP and CO2	36 Countries	Co-Integration and Ganger	GDP ≠ CO2
13.	Ghosh (2010)	1971–2006	GDP and CO2	India	ARDL Bounds/VECM	EC ↔ GDP EC → CO2
14.	Sharma (2011)	1985–2005	GDP, TO and CO2	69 Countries	Dynamic Panel Data Model	TO → CO2 GDP → CO2 EC → CO2
15.	Jaunky (2011)	1980–2005	GDP and CO2	36 Rich Countries	GMM & VECM Models	GDP → CO2
16.	Saboori et al. (2012)	1980–2009	GDP and CO2	Malaysia	ARDL Bounds Testing	CO2 → GDP
17.	Coondoo and Dinda (2006)	1960–1990	GDP and CO2	88 Countries	Co-Integration and Ganger	GDP ↔ CO2
18.	Menyah and Wolde-Rufael (2010)	1965–2006	GDP, EC and CO2 Labor & Capital	South Africa	ARDL and Co-Integration	CO2 → GDP EC → GDP EC → CO2
19.	Shahbaz et al. (2013)	1963–2008	GDP, CC and CO2 FDI and TO	South Africa	ARDL and Co-Integration	GDP → CO2 CC → CO2
20.	Park and Hoon (2013)	1991–2011	GDP, EC and CO2	South Korea	Markov switching model	GDP → CO2 EC → CO2
21.	Oh et al. (2010)	1990–2005	GDP and CO2	South Korea	Log Mean Divisia index	GDP → CO2
22.	Saidi and Hammami (2016)	1990–2012	GDP, EC and CO2	58 Countries	Dynamic Simultaneous	EC ↔ GDP (4 Panels) CO2 → GDP (LA & CRB)
23.	Al-Mulali and Binti-Chesab (2012)	1980–2008	GDP and CO2 EC and FDI	33 Sub-Saharan	Co-Integration and VECM	EC → GDP EC → FDI
24.	Hossain (2011)	1971–2007	GDP, EC and CO2 TO and URBN	NIC	Co-Integration and Ganger Panel Unit Root Tests	GDP → EC EC → CO2
25.	Kivyiro and Arminen (2014)	1971–2009	GDP and CO2 FDI and EC	6 Sub-Sahara Africa	ARDL Bounds Testing	EC → CO2 FDI → CO2 GDP → CO2
26.	Bouznit and Pablo-Romero (2016)	1970–2010	GDP, EC and CO2 Imports & Exports	Algeria	ARDL Bounds Testing	EC → CO2
27.	Pao and Tsai (2010)	1971–2005	GDP, EC and CO2	BRIC Countries	Co-Integration and Ganger	EC ↔ CO2 EC ↔ GDP CO2 ↔ GDP
28.	Wang et al. (2011)	1995–2007	GDP, EC and CO2	28 Provinces –China	Co-Integration and VECM	GDP → CO2 EC → CO2
29.	Bloch et al. (2012)	1965–2008	GDP, CC and CO2	China	Co-Integration and VECM	CC → GDP CC → CO2
30.	Farhani et al. (2014)	1971–2011	GDP, CC and CO2	China and India	Structural Break Unit Root Co-Integration and VECM	CC → CO2 (IND) CC ↔ CO2 (CHN)
31.	Lin and Wesseh (2014)	1971–2010	GDP, EC and EMP	South Africa	Non-Parametric Bootstrap	EC & EMP → GDP
32.	De Freitas and Kaneko (2011)	1970–2009	EC, EMP and CO2	Brazil	Decomposition approach	GDP → CO2 EMP → CO2
33.	Cowan et al. (2014)	1990–2010	GDP, EC and CO2	BRICS countries	Panel Causality Analysis Panel Bootstrap Method	GDP ↔ CO2 (RUS) GDP → CO2 (RSA) CO2 → GDP (BRA) GDP ≠ CO2 (CHN & IND) EC → CO2 (IND) EC ≠ CO2 (BRA & RSA) EC ≠ CO2 (CHN &RUS)
34.	Govindaraju and Tang (2013)	1965–2009	GDP, CC and CO2	China and India	Co-Integration and Ganger	EC → CO2 (CHN & IND)
35.	Pao et al. (2011)	1990–2007	GDP, EC and CO2	Russia	Co-Integration and Ganger	GDP ↔ CO2 GDP ↔ EC EC ↔ CO2
36.	Pao and Tsai (2011)	1980–2007 1992–2007	GDP, FDI and CO2	BRIC Countries (3) Russia	Panel Co-Integration Model	FDI ↔ CO2 GDP ↔ CO2 GDP ↔ EC GDP → FDI EC → CO2
37.	Maryam et al. (2017)	1991–2011	GDP, EC and CO2	BRICS Economies	Pooled OLS, Fixed Effects Random Effects	EC → CO2 EC → GDP
38.	Esso and Keho (2016)	1971–2010	GDP, EC and CO2	12 Sub-Saharan African	Co-Integration and Ganger	GDP ↔ CO2 EC → CO2

Note: (1) ↔, →, ≠, denote bidirectional causality relationships, unidirectional causality relationships, and neutral causality relationships, respectively; (2) CO_2, EC, CC, GDP, EMP, TO, URB and FDI are abbreviations for Carbon Dioxide Emissions, Energy Consumption, Coal Consumption, Gross Domestic Product (Economic Growth), Employment, Trade Openness, Urbanization and Foreign Direct Investments, respectively; (3) RSA, KE, DRC, IND, RUS, CHN, BRA, LA, CRB, SGP, IDN, THL, ML are abbreviations for South Africa, Kenya, Democratic Republic of Congo, India, Russia, China, Brazil, Latin America, Caribbean, Singapore, Indonesia, Thailand and Malaysia, respectively; (4) NIC, OECD, ASEAN, BRIC, BRICS, Panel ARDL, GMM, OLS and VECM are Newly Industrialized Countries, Organization for Economic Co-operation and Development, Association of Southeast Asian Nations, Brazil, Russia, India and China, Brazil, Russia, India, China and South Africa, Europe and North Asia, Latin America and Caribbean, Middle East and North Africa, and Sub-Sahara Africa, Autoregressive Distributed Lag, Generalized Method of Moments, Ordinary Least Squares and Vector –Error Correction Model respectively.

establish mechanisms of attaining green growth and sustainable development. For instance, in the case of South Africa, Odhiambo (2012) delineated that there is a unidirectional causal link flowing from economic growth to CO2 emissions, while both CO2 emissions and economic growth are Granger-caused by energy consumption. For the OECD and Non-OECD countries, results from Dinda (2009), deviates from other studies. Whereas CO2 emissions do not lead to an increase in economic growth for Non-OECD countries, they were found to increase in economic growth for OECD countries. In agreement, Richmond and Kaufmann (2006) found no significant causal links between economic growth and CO2 emissions and thus validated the neutrality of the hypothesis.

In terms of the determinants of carbon dioxide emissions (CO2) other moderating variables such as trade, urbanization, and globalization have been found to matter. For instance, there is a positive relationship of per capita GDP, trade openness and energy consumption, while urbanization has a negative relationship to CO2 emissions for low-income, middle and high-income panels Sharma (2011). However, energy consumption and per capita GDP were found to be statistically significant determinants of CO2 emission, while for a global panel of countries, urbanization, trade openness, energy consumption has negative effects on CO2 emissions.

2.3. Energy consumption and CO2 emissions towards environmental degradation in BRICS

Energy consumption and economic growth have contributed to Carbon Dioxide (CO2) emissions in BRICS Countries. Scholars devote a reasonable number of studies to examine how the environmental and social aspects of energy consumption related to causality between economic growth and CO2 emissions in each of the nations. The existence of causal links between energy consumption, pollutant emissions and real GDP for BRIC panel of countries, as a rise in energy consumption, increases CO2 levels, especially from Fossil oils Pao and Tsai (2010). According to Wang et al. (2011), there is causality between energy consumption and CO2 emissions, which implies that economic growth and energy consumption are major causes of CO2 emissions in China. In line with this, Bloch et al. (2012), confirmed the causal relationship running between CO_2 and coal consumption on the demand-side (D), and from coal consumption to GDP on the supply-side (S). In line with these findings, in India, coal consumption and industrial production Granger-cause CO2 emission, while the same was true for China with feedback effect between CO_2 emissions and coal consumption Farhani et al. (2014).

Furthermore, a significant causal index for consistent carbon dioxide (CO_2) emissions in South Africa is traced to rapid economic growth (Odhiambo, 2012). There is the existence of causal unidirectional link flowing from energy consumption to economic growth and from employment to economic growth Lin and Wesseh (2014). Shahbaz et al. (2013) studied the relationship between trade openness, financial development, economic growth, CO_2 emissions and coal consumption in South Africa. The findings showed that there exists a positive relationship among all variables; with economic growth rise resulting in a CO_2 emissions increase, while financial development reduces CO2 emissions and coal consumption leads to CO_2 emissions. In Brazil, De Freitas and Kaneko (2011) evaluated the determinants of CO_2 emissions changes from energy consumption to show that economic growth and demographic pressure are the leading forces that explain CO_2 emissions increase in Brazil.

The examination on causality relationship between economic growth, electricity consumption and CO_2 emissions in BRICS countries shows the existence of causal relationships between all the variables, but with different directions among BRICS countries (Cowan et al., 2014). For China and India, Govindaraju and Tang (2013) showed the existence of co-integration in China, but not in India, while both India and China showed a causal unidirectional relationship running from economic growth to CO_2 emissions. Relating to Russia, Pao et al. (2011) revealed the existence of a positive relationship between CO_2 emissions, energy use and real output (GDP). In summary, considering the different directions of causality, less compared with other economic and regional blocs, we find the need for more research on different energy sources and their growth-nexus and emissions impacts.

3. Data and methods

3.1. Model and methodology

The aim of this study is to investigate the impact of coal rents on CO2 emissions and how regulatory quality moderates this relationship in the BRICS panel of countries. As shown in the literature review section,

Table 2
Descriptions of variables.

Variable	Acronym	Definition	Data Source
Carbon dioxide (CO2) emissions per capita	CO2	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	WDI
Renewable Energy Consumption (% of Total)	RNW	Renewable energy consumption is the share of renewables energy in total final energy consumption.	WDI
Nuclear Power Generation (% of Total)	NPG	Nuclear power refers to electricity produced by nuclear power plants. Sources of electricity refer to the inputs used to generate electricity.	The U.S. Energy Information Administration
Coal consumption (thousand short tons)	CC	Coal consumption includes anthracite, subanthracite, bituminous, subbituminous, lignite, brown coal, and oil shale. It also includes net imports of metallurgical coke.	The U.S. Energy Information Administration
Economic Growth	GDP	Per capita GDP (Constant 2010 US $)	WDI
Coal Rents	CR	Coal rents are the difference between the value of both hard and soft coal production at world prices and their total costs of production.	WDI Selected studies on natural resource rents: (Abdulahi et al., 2019; Sinha and Sengupta, 2019)
Regulatory Quality	RQ	The index of Regulatory Quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	WDI (Danish et al., 2019; Halkos and Tzeremes, 2013)
Carbon Dioxide Damage (% of GNI)	CD	Cost of damage due to carbon dioxide emissions from fossil fuel use and the manufacture of cement, estimated to be US$30 per ton of CO2 (the unit damage in 2014 US dollars for CO2 emitted in 2015) times the number of tons of CO2 emitted.	WDI (Caldeira and Brown, 2019; Tol, 2005)

energy use (renewable and non-renewable consumption) has been vastly used in the literature. For the first time, we introduce the role of increased coal rents in CO2 emissions in BRICS economies. In general, early growth of income potentially creates more environmental contamination because of the expansion in utilization of goods. Also, income that arrives at an ideal level produces diminishing measures of contamination as people gets mindful of debasement of nature. However, we hypothesize that the use of economic regulations that supports green ecological guidelines may lead to reduction in emissions.

Besides testing for the role of coal rents, the EKC theory, which has been enormously assessed in the literature only presents differing results. Be that as it may, regulations on emissions assume a significant impact on reducing emissions. As shown in Table 2, this study departs from previous studies on the role of regulations and governance (Danish et al., 2019; Halkos and Tzeremes, 2013) by introducing an additional regulatory quality variable which serve as a restriction and law putting a price (carbon damage – CD) on CO_2 emissions and how to address climate change from concern to action. Thus, in this study, we interact both CD and regulatory quality index with coal rents to show the individual effectiveness of these regulations in achieving clean energy and green growth. Our motivation for this is to capture specific energy-related regulatory quality in terms of emissions. Following Lange et al. (2018), carbon damage is calculated as a multiplication of the additional social cost of CO_2 emissions from a particular energy source multiplied by the increase in the stock of the number of tons of CO_2 emitted in a year. Our intuition for interacting this variable with the rents that arise from the difference between world prices and cost of both hard and soft coal production is to capture the caution that BRICS countries take in the use of this energy source in the presence of rising damage. We do not isolate the direct effect of carbon damage on carbon emissions as it has been captured in the interaction, but rather examine how both classes of countries are guided in their use of this energy source for achieving climate change goals, measured by their levels of emissions.

Hence, to achieve the objectives of this study, we present a model with regulatory quality variables below. All variables are transformed into their logarithmic (ln) specifications to achieve a more intuitive result:

$$\mathrm{CO_{2it}} = \mathrm{f}(\mathrm{CR_{it}}, \mathrm{GDP_{it}}, \mathrm{RNW_{it}}) \tag{1}$$

$$\log(CO_2)_{it} = \beta_0 + \beta_1 \ln(CR)_{it} + \beta_2 \ln(GDP)_{it} + \beta_3 \ln(RNW)_{it} + \beta_4 \ln(CD)_{it} + \beta_5 \ln(CR * CD)_{it} + \mu_{it} \tag{2}$$

$$\ln(CO_2)_{it} = \beta_0 + \beta_1 \ln(CR)_{it} + \beta_2 \ln(GDP)_{it} + \beta_3 \ln(RNW)_{it} + \beta_4 \ln(RQ)_{it} + \beta_5 \ln(CR * RQ)_{it} + \mu_{it} \tag{3}$$

$$\ln(CO_2)_{it} = \beta_0 + \beta_1 \ln(CC)_{it} + \beta_2 \ln(GDP)_{it} + \beta_3 \ln(RNW)_{it} + \beta_4 \ln(RQ)_{it} + \beta_5 \ln(CC * RQ)_{it} + \mu_{it} \tag{4}$$

$$\ln(CO_2)_{it} = \beta_0 + \beta_1 \ln(NPG)_{it} + \beta_2 \ln(GDP)_{it} + \beta_3 \ln(RNW)_{it} + \beta_4 \ln(RQ)_{it} + \beta_5 \ln(NPG * RQ)_{it} + \mu_{it} \tag{5}$$

where CO_2 is CO_2 emissions, CR is the coal rents, RNW is renewable energy consumption, GDP is real GDP per capita which measures economic growth, CC is coal consumption which we include for comparison with coal rents, NPG is nuclear power generation also included for model sensitivity analysis, RQ is the regulatory quality, and CD is carbon damage; i represents the 5 BRICS countries; t denotes time (1990–2014); $\beta_i (i = 1,...,5)$ represents the slope parameters. All things been equal, we expect that $\beta_1 > 0$; $\beta_2 < or > 0$; $\beta_3 < 0$; $\beta_4 < 0$ *and* $\beta_5 < 0$. We also calculate individual effects in the estimated model, but we place emphasis on the interaction effects.

This study assesses both the short and long run estimates using the Pesaran et al. (1999) procedure. The examination continued with assessing the emissions-coal rents nexus presented in Eq. (1) in an Autoregressive Distributed Lag (ARDL: p, q) framework that incorporates lags of both emissions and regressors, given by:

$$\ln(CO_2)_{it} = \beta_i + \sum_{j=1}^{p} \delta_{ij} \ln(CO_2)_{it-j} + \sum_{j=0}^{q} \varphi_{i,j} Z_{it-j} + \mu_{it} \tag{6}$$

where, $Z_{it} = (CR_{it}, GDP_{it}, RNW_{it})$ which is a vector of explanatory variables used in this study. β_i represents the country-level fixed effects, δ_{ij} denotes slope of the lagged emissions variable and $\varphi_{i,\,j}$ represents slope of lagged explanatory variables.

The ARDL cointegration technique has been broadly utilized among researchers in empirical research due to its interesting econometric benefits when compared to traditional panel data models. The novel element of the test stems from its capacity to suit endogeneity issues in econometric models. It can at the same time gauge both short-run and long run parameters. The ARDL cointegration test is known for its adaptability regarding the appropriateness in mixed order of integration such as I (0) or/and I (1) however unquestionably not I (2). Pesaran et al. (1999) uncovered that the Pool Mean Group (PMG) estimator is reliable, robust and strong to lag orders and outliers.

3.2. Test processes

This study provides basic descriptive (summary) statistics and a Pearson correlation matrix to help understand features of the series. In panel data analysis, overlooking cross-sectional dependence may lead to genuine empirical concerns about the results. Hence the empirical course utilized in this study includes: (a) carrying out shock effect using the cross-sectional dependency test to eliminate possibility of spurious regression results which can potentially misinform energy policy formulation; (b) examination of stationary properties of main variables using the Fisher ADF unit root test and that of Im et al. (2003); (c) the Kao and the Pedroni (1999) cointegration test to assess equilibrium relationships; and (d) further testing the long and short run equilibrium relationship using the panel pooled mean group estimators; and (e) examine the direction of causality, by testing using the Dumitrescu and Hurlin (2012).

3.3. Data

The yearly information utilized in this study runs for the period from 1990 to 2014 for the BRICS countries (i.e., Brazil, Russia, India, China,

Table 3
Summary statistics.

Countries		LNCO2	LNCR	LNGDP	LNRNW
Brazil	Mean	0.612	−6.323	9.150	3.820
	Std. Dev.	0.166	2.166	0.140	0.054
	Minimum	0.336	−11.776	8.961	3.725
	Maximum	0.959	−3.818	9.392	3.909
Russia	Mean	2.438	−0.984	9.014	1.282
	Std. Dev.	0.081	0.604	0.261	0.061
	Minimum	2.316	−1.877	8.614	1.172
	Maximum	2.638	0.305	9.367	1.396
India	Mean	0.050	−0.104	6.827	3.880
	Std. Dev.	0.260	0.470	0.332	0.147
	Minimum	−0.342	−1.031	6.355	3.601
	Maximum	0.548	1.024	7.403	4.072
China	Mean	1.331	−0.509	7.681	3.077
	Std. Dev.	0.443	1.352	0.653	0.402
	Minimum	0.765	−2.787	6.592	2.459
	Maximum	2.023	1.576	8.715	3.529
South Africa	Mean	2.171	0.860	8.765	2.846
	Std. Dev.	0.065	0.414	0.118	0.058
	Minimum	2.045	−0.007	8.616	2.745
	Maximum	2.301	2.060	8.934	2.951
Overall	Mean	1.302	−1.412	8.287	2.981
	Std. Dev.	0.936	2.803	0.964	0.964
	Minimum	−0.342	−11.776	6.355	1.172
	Maximum	2.638	2.060	9.392	4.072

and South Africa). The variables considered include GDP per capita (measured in constant 2010 US$); Carbon dioxide (CO2) emissions per capita (which is measured in metric tonnes); Renewable energy consumption (measured as a percentage of total final energy consumption); Coal rents (also measured as a percentage of GDP); and Carbon dioxide damage (% of GNI) and Regulatory quality which is an index measured in points. As shown in Table 2, all data are sourced from the world bank development indicator (World Bank, 2018). Table 3 presents the summary statistics per country as well as for the overall BRICS panel group which includes mean, standard deviation, minimum and maximum values for the main variables of interest in the study. On average, Brazil has the highest GDP per capita (over the period, but the lowest coal rents among the BRICS countries. Average CO2 emissions per capita between 1990 and 2014 is highest in the Russian Federation followed by South Africa. Interestingly, while other nations have negative average coal rents over the period, South Africa has a higher positive coal rent.

4. Results and discussions

The result of cross-sectional dependence test is presented in Table 4, which shows evidence of lack of rejection of the null hypothesis of no cross-sectional dependence. Consequently, we adopt first-generation panel estimation methods. Results of level and first difference ADF Fisher and Im Pesaran Shin unit root tests are presented in Table 5. At level, only five of the variables are significant, that is, coal rents, GDP per capita, carbon-damage-coal-rents, and coal-rents-regulatory-quality at both 5%. However, all other variables are only significant at the first difference in both unit root test methods. Since the variables are of mixed others (level and first difference), the appropriate model estimation technique i.e. Panel Mean Group-ARDL was applied accordingly. In Table 6, we present results of the cointegration test. Both Pedroni and Kao cointegration tests suggests that there exist a long run cointegration relation between CO_2 emissions and its determinants in BRICS economies. Hence, we estimate the impact of coal rents, GDP per capita, renewable energy consumption, regulatory quality, and carbon damage on CO2 emissions for BRICS over the period 1990 to 2014.

As shown in Table 7, the results of the empirical regression model are consistent with the empirical evidence documented in the literature, albeit at different significance levels. Also, in Table 8, results of Dumitrescu and Hurlin panel causality test are presented. This was necessary to allow for an examination of the Granger non-causality from each explanatory variable to CO2 emissions in a heterogeneous panel setting. Coal rents is not statistically significant in the short run, but it is negative in the long run and is significant at 1% level, with a coefficient of −0.043. The negative long run coefficient implies that a 1% increase in Coal rents (the difference between the value of both hard and soft coal production at world prices and their total costs of production) will decrease CO_2 emissions by 0.043% in BRICS countries (Fig. 8). In Table 8, we find no granger causality between coal rents and CO2 emissions. This implies that coal rent does not aggravate the depletion of the environment as expected, unlike coal consumption with coefficient of 0.578 in the long run and 0.185 in the short run as shown by model 3, and a one-way causality which runs from coal consumption to CO2 emissions. Additionally, this finding is in line with past studies on coal-consumption-emission nexus (Pata, 2018). This finding is indicative to policymakers and environmental economist in BRICS economies as the emphasis is still placed on economic growth relative to the quality of the environment. That is, these economies are still at the scale stage of their growth trajectory (Shahbaz and Sinha, 2019). Also, as expected renewable energy consumption is negative and highly significant across all models in the long run.

Accordingly, the negative coefficient implies a 1% increase in renewable energy output will reduce CO_2 emissions by between 0.6% and 1.1% in the long run. There is also a one-way causality which runs from renewable energy consumption to CO2 emissions. The inverse link between both variables suggest that more consumption of energy from renewable sources enhances quality sustainability of the environment. This confirms that BRICS economies are above the growth trajectory and as such their environmental consciousness is not traded for growth anymore. For sensitivity tests between use of renewable and other non-renewable energy sources apart from coal, we introduce nuclear energy production, which is found to be statistically significant only in the long run. In this regard, the negative sign implies that a 1% increase in nuclear energy generation would reduce CO2 emissions by 0.101, thereby encourage the drive to achieve sustainable development in BRICS countries. Such an outcome suggests a paradigm shift on renewable energy sources like photovoltaic (solar energy) Biomass, hydro energy in BRICS economies. This position is consistent with the study of Emir and Bekun (2019) for the case of Romanian as well as Balsalobre-Lorente et al. (2018) for five EU countries. This also suggests that nuclear energy output has the propensity to drive economic growth in the BRICS economies at the same time ensuring less emission of greenhouse gas in the environment. This aligns with the findings by Bekun et al. (2019a, 2019b).

Table 4
Results from cross-sectional dependence test.

Test	Statistic	Prob.
Pearson LM normal	5.823	0.8299
Pearson CD normal	0.499	0.6176

Note. Null hypothesis: cross-sectional independence (CD ~ (0,1). Prob.

Table 5
Unit root test result.

Test	IPS		ADF-FISHER	
Variable	Level	Δ	Level	Δ
LNCO2	−0.9867	−4.6705***	−1.5310*	−7.0896***
LNCR	−2.9242**	−6.5391***	−0.5923	−8.4581***
LNGDP	−2.1010**	−3.6083***	2.9690	−4.3211***
LNRNW	−1.2842	−4.2652***	1.3069	−3.4511***
LNCC	−1.2917	−5.6028***	−1.1296	−6.8834***
LNNPG	−2.7837**	−5.8167***	−3.6687***	−9.7085***
LNCR*CD	−2.8529***	−6.4665***	−0.1290	−7.7663***
LNCR*RQ	−3.5064***	−6.7128***	−1.7951**	−6.7530***
LNCC*RQ	−1.0026	−5.8254***	−0.4947	−4.5638***
LNNPG*RQ	−1.2805	−5.4016***	−1.3474*	−4.7168***

Notes: Δ is first difference operator for the model with both trend and intercept at level. Lag length is automatically selected using Akaike information criterion. ***, ** and * represents a rejection of the null hypothesis of "unit root" at the 1%, 5% and 10% levels of significance respectively.

Table 6
Results from Pedroni and Kao cointegration results.

Pedroni cointegration test		
Statistic	Statistic	Prob
Panel v-Statistic	0.0285	0.5113
Panel Rho-Statistic	0.2082	0.5824
Panel PP-Statistic	−2.623	0.0043**
Panel ADF-Statistic	−3.978	0.0000***
Group Rho-Statistic	1.098	0.8638
Group PP-Statistic	−2.233	0.0127**
Group ADF-Statistic	−4.054	0.0000***
Kao cointegration test		
Statistic	t-Stat	Prob.
ADF	−1.5528	0.0355**

Notes: Dependent variable = CO_2 Emissions. v, rho, PP, ADF statistics are measured using Pedroni (2004, 1999). *p* values are given in parentheses. PP = Phillips-Perron; ADF = Augmented Dickey-Fuller. *** and ** represents a statistical rejection level of the null of no cointegration at 1% and 5% significance level respectively.

Table 7
Result of Pooled Mean Group with dynamic autoregressive distributed lag Model [PMG-ARDL (1,1,1,1,1)].
Model 1: $CO_{2it} = f(CR_{it}, GDP_{it}, RNW_{it}, (CR * CD)_{it.})$
Model 2: $CO_{2it} = f(CR_{it}, GDP_{it}, RNW_{it}, (CR * RQ)_{it})$
Model 3: $CO_{2it} = f(CC_{it}, GDP_{it}, RNW_{it}, (CC * RQ)_{it})$
Model 4: $CO_{2it} = f(NPG_{it}, GDP_{it}, RNW_{it}, (NPG * RQ)_{it})$.

Variables	(1)	(2)	(3)	(4)
Long run				
LNGDP	0.297***	0.432***	−0.210***	0.572***
	(0.0784)	(0.0645)	(0.0813)	(0.126)
LNRNW	−1.100***	−0.789***	−0.668***	−0.578***
	(0.165)	(0.153)	(0.0768)	(0.171)
LNCR	−0.0434*	−0.0527***		
	(0.0246)	(0.0142)		
LNCC			0.578***	
			(0.0701)	
LNNPG				−0.101**
				(0.0416)
LNCR*CD	0.0136			
	(0.0267)			
LNCR*RQ		0.0472***		
		(0.0172)		
LNCC*RQ			0.00178	
			(0.0139)	
LNNPG*RQ				0.0712***
				(0.0160)
Short run				
ECT (−1)	−0.271*	−0.383*	−0.351**	−0.354
	(0.143)	(0.205)	(0.153)	(0.263)
ΔLNGDP	0.182	−0.182	0.0143	0.0511
	(0.132)	(0.213)	(0.0777)	(0.152)
ΔLNRNW	−0.545***	−0.330	−0.278*	−0.662***
	(0.161)	(0.388)	(0.169)	(0.142)
ΔLNCR	−0.0239	0.0288		
	(0.0270)	(0.0243)		
ΔLNCC			0.185*	
			(0.113)	
ΔLNNPG				0.0525
				(0.0345)
ΔLNCR*CD	0.0384*			
	(0.0197)			
ΔLNCR*RQ		−0.00120		
		(0.00676)		
ΔLNCC*RQ			0.00193	
			(0.00499)	
ΔLNNPG*RQ				−0.0148*
				(0.00817)
Constant	0.624*	0.0816	−0.936*	−0.484
	(0.351)	(0.0757)	(0.490)	(0.370)

Note: CC = coal consumption; NPG = nuclear power generation. The fitted model is based on maximum lag 1 as suggested by Akaike information criterion. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ represents a statistical rejection level of the null hypothesis of no co-integration at 1%, 5% and 10% respectively.

Real GDP per capita is positive and has the expected sign. A 1% increase in real GDP per capita will lead to between 0.3%, 0.4% and 0.5% increase in CO2 emissions in models 1,2 and 4 respectively. For sensitivity analysis, model 3 presents a different result for emissions-growth nexus, with a rise in real GDP per capita decreasing emissions by 0.2%. With this result, we find that real GDP per capita play a significant role in aggravating CO_2 emissions in BRICS in line with most studies. With carbon emissions raised by a rise in real GDP per capita, there is impact on other sectors such as health, hence, the need to access the impact of regulations, and how CO2 emissions can be consequently mitigated. In the first model, regulations which include an interaction of coal rents and CO_2 damage costs was found to be statistically significant only in the short run, with coefficient of 0.0384. In model 2, regulatory quality index is found to be statistically significant only in the long run. However, other interactions of regulatory quality variables with coal consumption and nuclear energy production were not statistically significant. Accordingly, unlike our expectation, the positive coefficients imply that instituting regulations to coal consumption does not reduce the emissions to the environment. As a result, despite carbon damage cost expected to lead to low coal energy output and coal rents, emissions increase in line with higher damage costs. This is not unconnected to the drive for growth by BRICS countries.

Table 8
Results of the Dumitrescu and Hurlin (2012) Panel causality.

Null Hypothesis	W-Stat.	*P*-value	Causality flow
LNCR ≠ > LNCO2	1.5704	0.3671	LNCR ≠ LNCO2
LNCO2 ≠ > LNCR	1.4801	0.4478	
LNGDP ≠ > LNCO2	1.8001	0.2059	LNGDP → LNCO2
LNCO2 ≠ > LNGDP	2.8067***	0.0001	
LNRNW ≠ > LNCO2	3.8251	0.4513	LNRNW → LNCO2
LNCO2 ≠ > LNRNW	2.3936**	0.0276	
LNCC ≠ > LNCO2	1.4344	0.4922	LNCC → LNCO2
LNCO2 ≠ > LNCC	3.6749***	0.0000	
LNNPG ≠ > LNCO2	2.9309***	0.0023	LNCO2 → LNNPG
LNCO2 ≠ > LNNPG	0.4212	0.3601	
LNCR ≠ > LNGDP	2.6965***	0.0073	LNGDP ↔ LNCR
LNGDP ≠ > LNCR	2.0700*	0.0907	
LNRNW ≠ > LNGDP	3.5791***	0.0000	LNRNW ↔ LNGDP
LNGDP ≠ > LNRNW	6.3914***	0.0020	
LNCC ≠ > LNGDP	3.3382***	0.0002	LNCC ↔ LNGDP
LNGDP ≠ > LNCC	6.5127***	0.0000	
LNNPG ≠ > LNGDP	2.0605*	0.0936	LNNPG ↔ LNGDP
LNGDP ≠ > LNNPG	2.3906**	0.0279	
LNCR ≠ > LNRNW	1.4927	0.4360	LNCR → LNRNW
LNRNW ≠ > LNCR	3.5919***	0.0000	
LNCC ≠ > LNRNW	0.9153	0.8935	LNCC → LNRNW
LNRNW ≠ > LNCC	3.5616***	0.0001	
LNNPG ≠ > LNRNW	1.6634	0.2942	LNNPG ≠ LNRNW
LNRNW ≠ > LNNPG	1.8640	0.1719	
LNCR ≠ > LNNPG	1.3989	0.5283	LNCR ≠ LNNPG
LNNPG ≠ > LNCR	0.1281	0.1680	
LNCC ≠ > LNNPG	0.7324	0.6722	LNCC → LNNPG
LNNPG ≠ > LNCC	2.3319**	0.0352	
LNCC ≠ > LNCR	0.2466	0.2336	LNCC → LNCR
LNCR ≠ > LNCC	2.1411*	0.0712	

Note: ***, **, * represent 0.01,0.05 and 0.10 rejection levels respectively;
≠, → and ↔ represent No Granger causality, one-way causality and bi-directional causality, respectively.

Additionally, in the causality analysis (Fig. 9), we find a bidirectional causality between GDP per capita and coal rents, renewable energy consumption, coal consumption and similarly, nuclear power generation. Such causal link suggests alongside coal rents, each of these energy sources trigger GDP per capita and vice versa. The study found a one-way causality which runs from coal rents to renewable energy consumption; coal consumption to renewable energy consumption; and also, coal consumption to coal rents. This means that the rents from coal sources as well as its consumption propels renewable energy consumption, and as expected coal consumption drives coal rents. Hence, to achieve a reduction in the levels of CO_2 emissions from firms in BRICS countries and facilitate the efforts for green growth and sustainable development, more stringent regulations are inevitable. Thus, policy and decision-makers should explore alternative measures of increasing coal energy output thereby increasing coal consumption and ensure that environmental degradation is minimized to the lowest level through adopting modern technologies in safeguarding carbon emissions. This result differs for regulatory quality as used in previous studies which find different impact of governance indicators on CO2 emissions across countries (Danish et al., 2019; Halkos and Tzeremes, 2013). One reason for our result could be due to our use of energy related regulatory quality variable which is carbon damage.

5. Conclusion

Carbon dioxide (CO_2) emissions, especially in robust metrics, could be hazardous to lives that the environment shelters. Although several variables could be trailed when assessing its prevalence in recent decades, the thought of Coal rents as causal indices remains abstract.

Thus, the main objectives of this research were to examine if there exists any relationship between Coal Rents and Carbon dioxide (CO_2) emissions in BRICS countries and test the moderating roles of carbon damage and regulatory quality index. Whereas the literature on energy consumption and economic growth has been explored to a reasonable extent for BRICS and the rest of nations for many years, there has been no studies that have investigated the causal relationship between Coal Rents and CO_2 emissions. We adopt the panel mean group autoregressive distributed lag model (PMG-ARDL) after conducting appropriate tests on the data in order to overcome any statistical limitations at least to the knowledge of authors. Based on the expected results apriori to the empirical analysis, overall, the study achieved its main objectives. Other than studies adopting natural resource rents in general, this study's novelty is in its presentation of coal rents vs. coal consumption and other energy sources as determinants of CO2 emissions in BRICS economies. Although the study did not have many previous studies with similar variables of interest (Coal rents), it builds on the strengths of past studies like those of Saidi and Hammami (2016); Maryam et al. (2017) by focusing the analysis to BRICS.

Part of what we find in this outcome is that in BRICS countries, coal rents have a significant and negative relationship with CO_2 emissions. Thus, like the impact of renewable energy sources, an increase in coal rents (unlike coal consumption), will reduce CO_2 emissions and help efforts towards achieving sustainable development. Besides, the estimation results for Coal consumption show a positive and statistically positive impact on CO_2 emissions, implying that an increase in coal energy consumption would increase CO_2 emissions.

Equally, the results of the estimation for renewable energy consumption and nuclear power generation indicate a statistically significant and negative relationship with CO_2 emissions. This demonstrates that an increase in renewable energy output and nuclear energy output will result in a reduction to CO_2 emissions for sustainable development. Finally, the study interacted the logarithm of coal rents and carbon dioxide damage cost to test for the impact of energy policy variables and regulatory quality. The estimation results outline that the relationship between regulations and CO_2 emissions is positive and statistically significant. Accordingly, the findings suggest that consumption of coal in driving economic development is not viable. Hence, imposing more stringent regulations to coal production in addition to CO_2 damage costs is expected to reduce coal exploitation and thus coal rents, which could in turn reduce the levels of CO_2 emissions to encourage achieving sustainable development.

The research findings illustrate that more coal rents from coal natural resource exploration would increase coal consumption, which in turn increases the level of CO_2 emissions and these will adversely affect efforts made towards achieving sustainable development. Likewise, increasing coal energy output for economic growth would increase levels of CO_2 emissions and negate sustainable development. Furthermore, imposing regulations on coal consumption would positively affect CO_2 emissions levels. Such findings would infer that instituting regulations for curbing pollution emissions and Greenhouse gases may reduce the levels of CO_2 emissions, and thus support the objective of sustainable development. Additionally, there is a positive relationship between real GDP per capita and CO_2 emissions. Hence, an increase in energy use for economic growth would increase levels of CO_2 emissions.

Accordingly, an increase in the renewable and nuclear energy consumption would reduce CO_2 emissions levels and support efforts for sustainable development. Therefore, these findings have implications for policymakers. First, by honouring and sustaining the commitments made by each country to the COP21 will be a stride in the right direction as Climate Action is Sustainable Development Goal No. 13 under the UN 2030 Agenda for Sustainable Development (SDGs). For instance, following the release of the SDG Index and Dashboard by Bertelsmann Stiftung-SDSN, the BRICS countries were ranked; 53, 47, 110, 76 and 99 respectively in their efforts for sustainable development (SDG Index and Dashboard, 2016). Although in most of the BRICS countries the CO_2 emissions per capita levels are reducing, more efforts are necessary to maintain momentum towards green growth and sustainable development.

Secondly, coal production costs should continue to increase so that coal rents would be negative and thus deter the exploitation of coal for energy consumption, thereby reducing CO_2 emissions from energy consumption. According to the SDG Index and Dashboard, this will be one of the key instruments in achieving SDG 13 target 1 by 2030 as stipulated under the UN 2030 Agenda for Sustainable Development, thereby paving way for attaining green growth and sustainable development. However, this would require countries to engage in energy policies that conserve the environment and social well-being to be able to reduce carbon dioxide emissions. Hence, the study recommends consideration of strict energy and environmental-related regulatory policies to encourage an increase in the use of energy consumption from renewable energy sources, such as solar, wind, among others, which will lower carbon dioxide emissions and pave way for attaining green growth and sustainable development.

Beyond the current benefits of coal rents, policymakers should pay attention to the introduction and imposing of other stringent regulations in addition to carbon damage costs, as a means of curbing carbon dioxide emissions, pollution and the subsequent effects to environmental and social degradation, without harming economic growth. Since the research findings have found regulations to positively affect CO_2 emissions levels, this highlights the significance of other non-economic elements in enabling the reduction of CO_2 emissions to succeed with green growth and sustainable development. Accordingly, other policy implications and recommendations consist of focusing on improving the basics for the accomplishment of the green growth and sustainable development agenda. All countries need to explore the possibility of introducing and expanding energy consumption from fossil fuels to renewable and nuclear power output. In consideration of the research findings, it is evident that renewable and nuclear energy consumption would have a positive effect to green growth and sustainable development, given its negative correlation to carbon dioxide (CO_2) emissions.

Similarly, many researchers have suggested the need to introduce technology, such as Clean Coal Technology (CCTs) in the coal energy systems for increasing efficiency and lowering greenhouse gases. Therefore, strengthening research and development initiatives would play a crucial role in the introduction and application of new technology for coal consumption to mitigate carbon dioxide (CO2) emissions and ensure accomplishment of green growth and sustainable development. However, to succeed in all these policies, there would be a need for an increase in government spending or attracting Foreign Direct Investments (FDI) to ensure that the efforts of attaining green growth and sustainable development do not harm the all overarching governments' objective – economic growth (real GDP).

Like all other research studies, this particular study is not without some limitations. First, some of the key determinants of sustainable development, such as social-economic well-being, climate change vulnerability, could not be included into the statistical models due to the absence of time-series data and secondly, in order to appropriately capture the role of 'energy/environmental'-based regulations, merely interacting carbon damage and regulatory quality index with coal rents and other energy sources may require further research to give support or confirm the empirical findings of this study. After this limitation, this study without exceptions presents suggested areas of further studies to bridge the existing gaps in the literature related to energy consumption, economic growth and carbon dioxide (CO_2) emissions and the use of resource rents. Accordingly, it is recommended that considerable attempts should be made to examine the relationships between coal rents and CO_2 emissions at individual country or regional levels.

The literature has indicated that an increase in economic growth brings about an increase in coal energy consumption, thus the externalities of energy consumption would set back economic growth. This scenario creates policy implication for policymakers and suggests that reducing carbon dioxide (CO_2) emissions or imposing regulations to coal consumption would lead to a reduction in economic growth, which could further frustrate efforts for the accomplishment of the UN 2030 Sustainable Development Agenda and green growth. On the premise of this result, the study highlights the following policy implication directions. First, since emissions of carbon dioxide are closely influenced by coal rents, authorized regulatory bodies may review operational policies to align interest groups for the peak benefit of enhancing sustainable development goal 2030. Second, renewables and nuclear energy output could arguably be sustained, the role of CO_2 emissions aiding environmental degradation could be effectively policed as well as the imposition of regulatory reforms on coal production would input a measurable balance on coal rents consequently initiate ripple effect on the reduction of CO_2 emissions in BRICS.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2019.136284.

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