ENERGY CONSUMPTION AND ECONOMIC GROWTH: THE RELATIONSHIP BETWEEN COAL RENTS AND CARBON DIOXIDE CO2) IN BRICS COUNTRIES

By

GUMEDE, Iga Moses

THESIS

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF DEVELOPMENT POLICY

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Committee in charge:

Professor Wonhyuk LIM, Supervisor ____________________

Professor Booyuel KIM ____________________

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Approval as of December, 2017

ENERGY CONSUMPTION AND ECONOMIC GROWTH: THE RELATIONSHIP BETWEEN COAL RENTS AND CARBON DIOXIDE (CO_2) EMISSIONS IN BRICS COUNTRIES

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ABSTRACT

ENERGY CONSUMPTION AND ECONOMIC GROWTH: THE RELATIONSHIP BETWEEN COAL RENTS AND CARBON DIOXIDE (CO_2) EMISSIONS IN BRICS COUNTRIES

By

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The BRICS economies, composed of Brazil, Russia, India, China and South Africa - are major contributors of Carbon Dioxide (CO_2) emissions among the Newest Industrialized Countries (NICs). BRICS economies possess massive natural resource endowments especially fossil fuels (e.g. Coal), leading to greater exploitation of coal for energy consumption, while more available energy contributes to GDP growth. Although BRICS countries have pledged to curb CO_2 emissions by 2030 at the COP21 (the Paris Agreement), complying with these pledges may be a difficult task without compromising economic growth. This study investigates the relationship between Coal Rents and CO_2 emissions, in the presence of regulations (measured by the charge on CO_2 damage) for BRICS and a randomly selected Panel of Selected Countries (**PSC**) consisting of 60 coal exploring economies. The study utilizes the Pooled Ordinary Least Squares (OLS) and Fixed Effects Econometric Models on panel data from 1990-2015 from the World Bank Development Indicator (WDI, 2017) for the variables of interest. The study empirical results indicate that in BRICS economies, coal rents have a significant and positive impact on CO_2 emissions, which in turn negatively affects sustainable development. While regulations have a significant and positive impact to CO_2 emissions and thus negatively affect sustainable development. Overall from a policy standpoint, the empirical estimates call for policymakers in both BRICS and PSC to pay close attention to low-carbonization measures for sustainable development without compromising economic growth. These measures include encouraging energy consumption from renewable and nuclear energy output, reducing incentives for coal consumption, application of Clean Coal Technology, and re-considering instituting regulations on carbonization.

***Keywords*: Coal Rents, CO_2 Emissions, Energy Output, Economic Growth, Sustainable Development, Pooled Ordinary Least Squares and Fixed Effects Models.**

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ENERGY CONSUMPTION AND ECONOMIC GROWTH: THE RELATIONSHIP BETWEEN COAL RENTS AND CARBON DIOXIDE (CO_2) EMISSIONS IN BRICS COUNTRIES

By

GUMEDE, Iga Moses

2017

DEDICATION

I dedicate this Research Thesis to my Beloved Wife and Best Friend, Barbara GUMEDE and our five lovely Daughters;

Jackline, Joseline, Jessica, Julianna and Junetta.

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First and foremost, praises and gratitude to Lord God, the Almighty for all the blessings, protection and love showed to me throughout the program and completion of Thesis. "Delight yourself also in the Lord, and He will give you the desires of your heart." **Psalm 37:4**. Secondly, I would like to extend my deepest appreciation to ***Professor Wonhyuk LIM***; my major supervisor and ***Professor Booyuel KIM***; second supervisor, whose expert and invaluable guidance, advice, motivation, constructive criticism, encouragement and support during this study and Advanced Research Seminars, made it possible. Thirdly, I would like to thank all my Professors at KDI School of Public Policy and Management for the knowledge and wisdom they have imparted to me during my entire study period.

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God Bless you All and continue to Protect you Always!

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DEFINITION OF KEY TERMS

1. **Coal Rents**: Are calculated as the difference between the price of coal commodity at world prices and the average domestic cost of production for coal, by estimating the world price of units of coal commodities and subtracting estimates of average unit domestic costs of extraction. In some countries earnings from natural resources, especially fossil fuels and minerals, account for a sizable share of GDP, and much of these earnings come in the form of economic rents - revenues above the cost of extracting the resources. Coal rents are measured at world prices without considering domestic government subsidies, given that coal is traded on world commodity markets like other precious natural resources such as Gold, Oil, etc. (World Bank, 2011).
2. **Green Growth**: 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.
3. **Sustainable Development**: Economic growth or development that considers the environment and improves social well-being of all people thereby creating opportunities for future generations.
4. **Carbon Dioxide (CO2) Emissions**: Are pollutants stemming from the use of fossil fuels, like coal; and consumption of solid or liquid fuels such as gas fuels and gas flaring.
5. **GDP per Unit of Energy Use:** Is the PPP GDP per kilogram of oil equivalent of energy use. PPP GDP is gross domestic product converted to 2011 constant international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as a U.S. dollar in the United States (World Bank, 2011).
6. **Carbon Dioxide Damage**: Represents the present value of global damage to economic assets and to human welfare over the time the unit of pollution (carbon dioxide) remains in the atmosphere. CO_2 damage is estimated to be $20 per ton of carbon (the unit

damage in 1995 U.S$) times the number of tons of carbon emitted (World Bank, 2011).

7. **Regulations:** These are restrictions, fines or laws that put a price on carbon emissions and address climate change from concern to action. Regulations on carbon help shift the burden of damage from greenhouse gas emissions back to those who are responsible for it and who can reduce emissions. For this study, regulations are derived from the logarithm of Coal rents and carbon dioxide damage interactions.

8. **Renewable Energy:** Energy that is generated from resources that are naturally replenished (Non-depletable Resources) on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy is considered "clean energy" or non-carbohydrate energy as its generation process for energy consumption does not produce carbon dioxide like fossil fuels.

9. **Nuclear Energy**: Energy that is generated by reaction of atoms into small particles that holds neutrons and protons through the nuclear fission process. Nuclear energy is also considered "Clean energy" or non-carbohydrate energy as its generation process for energy consumption does not produce CO_2, associated to fossil fuels such as coal.

10. **BRICS Countries**: Are five major emerging national economies: Brazil, Russia, India, China and South Africa, which are all leading, developing or newly industrialized countries and members of the G-20 Nations. They are distinguished by their large and fast-growing economies and significant influence on regional and global affairs.

11. **Panel of other Selected Countries (PSC)**: Totaling 60 countries who are coal exploration and coal energy consuming economies and thus produce a lot of CO_2 emissions. The total of sixty (60) nations has been randomly selected based on these economies dependency on coal consumption for energy output and availability of data for the variable of interest (Coal Rents) as obtained from World Bank Development Indicators (WDI) 2017.

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LIST OF ACRONYMS

2SLS	Two-Stage Least Squares
ARDL	Autoregressive Distributed Lag Bounds Test
ASEAN	Association of Southeast Asian Nations
BRICS	Brazil, Russia Federation, India, China and South Africa
CCT	Clean Coal Technology
CO_2	Carbon Dioxide Emissions
EKC	Environment Kuznet's Curve
FDI	Foreign Direct Investment
FE	Fixed Effects
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GMM	Generalized Method of Moments
IV	Instrumental Variable
NIC	Newly Industrialized Countries
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
PSC	Panel of Selected Countries
SDGs	UN 2030 Sustainable Development Goals
VECM	Vector Error-Correction Mechanism
WDI	World Bank Development Indicator

CHAPTER 1: INTRODUCTION

1.1 Background of the Study and Overview

Historically, energy supply and consumption has been the pivot of economic growth and the driver for sustainable development for many countries, and this tendency will persist. Increasing economic activities across many countries and consequent use of large quantities of fossil fuels like coal for energy consumption, will result in more CO_2 emissions, contributing to externalities of climate change and global warming. Hence, the subject of the causal links between energy consumption, economic growth and CO_2 emissions has become one of the most debated topics, as this relationship's direction relevance is of importance to policymakers. A number of studies have investigated the nature of causal links between energy consumption and economic growth with different hypothesis settings at country-level and in panel of countries, such as BRIC, BRICS, OECD and Sub-Saharan African Countries, amongst others. The findings of many of these studies have confirmed the existence of both bi-directional and uni-directional relationships between energy consumption and economic growth, and that consumption of energy deteriorates the environment (Akinlo, 2008; Odhiambo, 2010; Apergis & Payne, 2010; Cowan, Chang, Inglesi-Lotz & Gupta, 2014).

Similarly, ***BRICS countries*** are heavily dependent on energy intensive sectors such as construction, mining and manufacturing for economic growth and industrialization. These countries are facing a rapid increase in population, lifestyle changes and urbanization, which, in turn, has created an increase in energy consumption demand, and thus poses a serious threat to climate change and global warming. This has led to concerns about how countries would achieve green growth and sustainable development; and manage their economic and energy needs with policies that are social inclusive and environmental sustainable. These policy challenges call for concerted efforts by policymakers to better explore the causal links between energy consumption, economic growth and CO_2 emissions.

The way in which energy is sourced, generated and consumed harms the environment and social well-being through pollution, GHGs, and CO_2 emissions **(Appendix 1)**. Energy consumption externalities emanates mostly from energy fossil oils sources, such as coal, which have a significant impact on 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. The use of energy, however, has substantial social and environmental implications in addition to impacts on the supply-side. 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. Henceforth the need to further examine the relationship between economic growth, energy consumption and CO_2 emissions, with special emphasis on coal consumption, which is considered "dirty" and associated to causes of global warming and climate change.

1.2 Statement of the Problem

Various studies have examined the causal links between economic growth and coal consumption (Li & Li, 2011; Odhiambo, 2016; Apergis & Payne, 2010). 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. **Appendix 2, 3, and 4** provide graphs that represents the coal resources, coal production (in million tons) and coal consumption (in million tons), while **Appendix 5** represents CO_2 emissions for the BRICS countries for the period 1990 – 2015 respectively. The Appendixes demonstrate the BRICS countries' current dependence on coal as their key source of energy for economic growth and subsequent sustainable development.

Given the high dependence on coal consumption and the resulting high levels of CO_2 emissions, understanding the relationship between coal rents and sustainable development would be useful. In economics, rent is the surplus value after consideration of the difference between output and selling price, taking into consideration of all costs of production. Similarly, ***Coal Rents*** are the difference between the value of both hard and soft coal production at world prices and their total costs of production – "difference between revenues and extraction cost". Given that coal is traded on the world market as "precious metals", world prices for commodity prices are utilized for purposes of benchmarking rents from natural resources, overlooking any subsidies from governments to local extraction firms. Coal rents, which is resource rent from coal production provides incentives to coal exploration companies to explore more coal for energy consumption, which in turn has externalities towards levels of CO_2 emissions. Natural resource rents are usually positive, unless maximization of the benefits from the resource was constrained by other macro-level factors, such as marginal extraction costs. Natural resource rents could be easily defined for any level of natural resource utilization, on condition that information is available related to marginal benefits and production costs of natural resource, as natural resources rents may affect long-term economic growth (Arnason, 2008; Mehrara & Baghbanpour, 2015). Fortunately for this study, the data available from WDI 2017 indicates that coal rents are positive at world prices, regardless of subsidies at country-level for BRICS countries (Refer to **Appendix 9, 10, 11, 12** and **13**).

Despite the negative externalities of CO_2 emissions from coal consumption, coal rents have a positive impact to economy growth. Even though the majority of coal production is used for energy consumption, coal rents as part of natural resources still represent a large part of GDP contributions in BRICS economies. **Appendix 6** and **Appendix 7** shows the coal rents and GDP per capita, respectively in BRICS economies for the period 1990 – 2015. **Appendix 8** shows coal rents contribution to GDP of top 10 economies in the world, with some BRICS economies such as South Africa, China, India and Russia. Therefore, the direction of the causal links between coal rents and CO_2 emissions would provide policy makers guidelines on how to design policies that would create a balance between economic development, environmental sustainability and social sustainability, thereby implementing ways that move their countries towards green growth and sustainable development.

In addition, BRICS countries and many other countries that are signatory to the Kyoto Protocol, have acknowledged that "climate change is one of the greatest challenges and threats towards achieving green growth and sustainable development" and have made varying pledges to reduce GHGs emissions by 2020. The recent 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 the pollution, CO_2 emissions and eliminate climate change and global warming (Esso & Keho, 2016). For instance, South Africa has pledged to reduce GHGs emissions to 34% by 2020, but is involved in more construction of coal-fired power plants, including the Medupi Power Plant funded by the African Development Bank, the World Bank and other financial institutions. According to Cowan, Chang, Inglesi-Lotz, & Gupta (2014), BRICS countries signed a "multilateral agreement on climate co-operation and the green economy" during the 5^{th} BRICS Summit in 2013, which will ensure the exchange of technical and financial support to combat the negative impact of climate change on developing countries.

Due to coal being an abundant and low-cost source of energy for many countries, together with the increased need for energy supply and global warming concerns, the relationship between energy or coal consumption, economic growth and CO_2 emissions has been examined in a number of studies (Menyah & Wolde-Rufael, 2010; Park & Hong, 2013; Oh, Wehrmeyer, & Mulugeta, 2010; Al-Mulali & Binti-Chesab, 2013; Shahbaz, Tiwari & Nasir, 2013; Pao & Tsai, 2010; Wang, Zhou, Zhou & Wang, 2011; Bloch, Rafiq & Salim, 2012; Farhani, Shahbaz & Ozturk, 2014; Odhiambo, 2012; Lin & Wesseh, 2014; De Freitas & Kaneko, 2011; Cowan, Chang, Inglesi-Lotz, & Gupta, 2014; Govindaraju & Tang, 2013; Pao & Yang, 2011; Pao & Tsai, 2011; Esso & Keho 2016) (See **Table 1** – Summary of the Literature Review for this Topic).

Previous empirical studies utilized varied energy variables and modeling techniques but their results were inconclusive or mixed. For instance, some studies in the literature review for BRIC, BRICS, ASEAN, OECD, African countries and Sub-Saharan countries applied the Panel Causality Analysis, Panel Bootstrap Method, Co-integration Technique and Granger Causality Testing on CO_2 emissions, Energy and Coal Consumption, real GDP, Employment, FDI, Trade openness, Output, Labor, Capital, Income, and Price as energy variables (Al-Mulali & Binti-Chesab, 2013; Shahbaz, Tiwari & Nasir, 2013; Pao & Tsai, 2010; Wang, Zhou, Zhou & Wang, 2011; Bloch, Rafiq & Salim, 2012; Farhani, Shahbaz & Ozturk, 2014; Odhiambo, 2012; Lin & Wesseh, 2014; De Freitas & Kaneko, 2011; Shahbaz, Tiwari, & Nasir, 2013; Cowan, Chang, Inglesi-Lotz, & Gupta, 2014; Govindaraju & Tang, 2013; Pao & Yang, 2011; Pao & Tsai, 2011). More recently, Maryam, Mittal & Sharma (2017) attempted to find the empirical relationship among three variables, i.e., CO_2 emissions, economic growth rate and energy consumption in a panel of BRICS countries for the annual data-set for the period 1991 to 2011, using both fixed and random effects and then unit root test. **Table 1** presents the details of major studies on this topic, including methodology, data, and variables used as well as the key findings in respect to the relationship between the variables of interest.

Consequently, results from these studies indicated the existence of causality between CO_2 emissions, energy consumption and real output, thereby an increase in energy consumption increases CO_2, especially from fossil fuels for the BRIC panel of countries and other countries (Pao & Tsai, 2010; Cowan, Chang, Inglesi-Lotz, & Gupta, 2014). While the study by Al-Mulali & Binti-Chesab (2013) showed that energy consumption had played a significant part in increasing both financial development and economic growth for the economies, with the externalities of high CO_2 emissions. In addition, Menyah & Wolde-Rufael (2010) recommended introducing alternative sources of energy to substitute coal, which is the leading source of CO_2, so that South Africa could satisfy its energy needs and at the same time lessen the CO_2 emissions. On the other hand, Shahbaz, Tiwari & Nasir (2013) emphasized controlling the environment from degradation through efficient use of energy for economic growth in South Africa. While Maryam, Mittal & Sharma (2017) concluded that CO_2 emissions are positively related to GDP and energy consumption among BRICS countries, and their rate of economic growth will have significant climate change impacts.

Notwithstanding, most studies in the literature reviewed focus either on the nexus of energy-output, or output-emissions in a number of countries, but do not explore the causal link between coal rents and CO_2 emissions (**coal rents-emissions nexus**). It is important to note that with the abundance of fossil fuels resources, like coal, within the BRICS and the fact that "dirty coal" is a major component of their energy-mix, high coal rents (difference between the value of both hard and soft coal production at world prices and their total costs of production) would be an incentive for mining companies to extract more coal for energy consumption. However, considering the environmental costs, examining the coal rents-emissions nexus should be considered of greater importance to policymakers rather than the energy-output or output-emissions nexus, which have been extensively investigated in previous studies (See **Table 1** – Summary of the Literature Review for this Topic).

In fact, there have been four elements of previous research on the energy-output or output-emissions nexus. They have focused on the relationship between economic growth and CO_2 emissions, economic growth, energy consumption and the environment, thus focusing on the relationship between energy consumption and economic growth, relationship between coal consumption, economic growth, and relationship between energy consumption, economic growth and CO_2 emissions. Moreover, few studies have concentrated on the nexus of energy-output or output-emissions in the BRICS countries, let alone the study of the causal link between coal rents and CO_2 emissions.

In addition, in all the studies under the literature reviewed, none have concurrently utilized the 2 methodology of Ordinary Least Square (OLS) and Fixed Effects (FE) or Random Effects (RE) to ensure the control of statistical limitations. Therefore, the lack of research in respect to the causal link between coal rents and green growth in BRICS and other countries, calls for a clear identification and understanding of the determinants of CO_2 emissions. Hence, this research attempts to examine the relationship that may exists between coal rents and green growth in BRICS and other selected countries to bridge the existing gap in the literature, and is of great importance to policymakers and energy economists. This study is further motivated by the fact that no studies have examined the relationship between economic growth, energy consumption and CO_2 emissions using the three methodologies (OLS and FE/RE), while applying CO_2 emissions as independent variable, together with regulations as the policy variable and coal rents as the key variables of interest.

1.3 Importance of the Study

Globally, energy is a key factor in the process of industrialization and urbanization. However, the way in which energy is consumed leads to externalities of environmental and social degradation. Whereas coal continues to be the dominant energy source for developing economies, and largest single fuel used for electricity generation worldwide in respect to non-renewable energy-mix, it is considered a dirty source of energy and is associated with climate change and global warming. This phenomenon has generated condemnation from United Nations, International agencies and pressure groups, and has resulted into 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, social inclusion and environmental sustainability, as they move towards green growth and the sustainable development agenda. In essence, developing countries insist that green growth policies are expensive to implement and may affect economic growth, rather than building sustainable development. Hence, they may continue addressing the rising energy consumption demand for meeting the sustainable development goals, through building low-cost coal-fired power generation. Such initiatives would require exploring critical and super-critical coal technologies in addition to carbon capture and sequestration for energy efficiency in coal-fired power plants.

Although coal-fired power plants are considered the highest generators of greenhouse gas emissions, their contribution to the energy-mix and consequent economic development should not be underestimated. The situation is not expected to change dramatically in the near future and poses serious environmental and social challenges. Considering the confirmed existence of causality between economic growth, energy consumption and CO_2 emissions, there is a need to further explore ways in which countries can transit to green growth and sustainable development. Despite continued pressure from international environmental agencies on countries to engage in low-carbon initiatives, policymakers are concerned that such initiatives would be costly and negatively affect economic growth. This calls for better ways to establish other relationships in respect to coal consumption, which could provide ways to achieve green growth and sustainable development; without compromising economic growth, on the one hand, and environment and social well-being, on the other.

This study on causality between coal rents and CO_2 emissions is of importance in providing the necessary inputs to the policy of developing countries to establish how the cost of coal production would affect CO_2 emissions and subsequently sustainable development. In establishing the relationship between coal rents and CO_2 emissions in BRICS countries, the study will provide the platform to minimize the environmental and social impacts related to burning coal and advocate for clean energy for economic growth and sustainable development.

The purpose of this study is to fill the existing gap by providing additional empirical investigation to the current literature. The expected results from the empirical study will enable policymakers to find out how coal rents (difference between the value of both hard and soft coal production at world prices and their total costs of production) affects the levels of CO_2 emissions in BRICS economies and the PSC.

The choice of the BRICS Countries is an interesting case study given that CO_2 emissions and sustainable development are major ongoing concerns for policymakers and energy environmentalist in both developed and developing countries. In fact, energy consumption is a fundamental element in economic development, and it is estimated that more than 70% of the energy demand for the population and industries within BRICS and other countries around the world depend heavily on coal consumption. For instance, BRICS economies' energy output is highly dependent on coal consumption (**See Appendix 14**), while at the same time share about 30% of the World GDP (**See Appendix 15**). Furthermore, the choice of this region is also motivated by the fact that, despite the growing literature on the causal links between output, energy consumption and pollution, not many studies have been conducted on the BRICS, the top CO_2 emitters in the world (**See Appendix 16**).

1.4 Objectives of the Study

Energy consumption supports a pivotal role in economic growth and it is considered the driver for sustainable development for most countries. Unfortunately, the inefficiency of the overall energy system has major environmental and social drawbacks. The BRICS countries, whose economic growth heavily relies on energy intensive sectors such as construction, mining and manufacturing, have been faced with economic, energy and environmental sustainability policy challenges, given international pressures on climate change and global warming together with efforts to attain green growth and sustainable development.

Notwithstanding, BRICS countries have abundant fossil fuels like coal, and need to continue utilizing such energy sources for sustainable development. Considering the need to increase levels of recent economic growth in BRICS countries, CO_2 emissions are also expected to increase as large quantities of coal will be utilized for energy consumption contributing to global warming by BRICS countries. Like many coal consumption dependent countries, BRICS countries need to examine coal rents (the cost of coal consumption) vis-à-vis the drawbacks to environmental and social- well-being, in order understand the direction towards green growth and sustainable development. 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 CO_2 emissions.

The primary objective of this study is to examine the relationship between coal rents and CO_2 emissions in the BRICS panel of countries, using panel data over the period between 1990 and 2015 by focusing on panel-specific analysis. In addition, this study makes a comparative analysis of the level of causality of the PSC with BRICS countries, to establish the relationship between coal rents and CO_2 emissions for green growth and sustainable development. The total selection of the PSC, which are sixty (60) coal exploring economies is random-based and relies on data availability **(See Appendix 17**).

1.5 Research Questions

In order to investigate the causal link between coal rents and carbon dioxide (CO_2) emissions and achieve the policy objectives, the study posits the following research questions;

(i) How do coal rents relate with carbon dioxide (CO_2) emissions?

(ii) How does coal energy output relate with CO_2 emissions?

(iii) How does renewable and nuclear energy output relate with CO_2 emissions?

(iv) How do regulations to CO_2 emissions compare between BRICS and other coal exploring countries?

1.6 Research Hypothesis

In order to answer the above research questions, this study identified the following hypotheses;

(i) I expect coal rents to have a positive relationship with CO_2 emissions.

(ii) I expect coal energy output to have a positive relationship with CO_2 emissions.

(iii) I expect renewable and nuclear energy output to have a negative effect to CO_2 emissions.

(iv) I expect regulations of CO_2 emissions to be negative and similar in both BRICS and other coal exploring economies.

1.7 Structure of Data

This study utilizes panel data from 1990 to 2015, obtained from the WDI 2017, to examine the causal relationship between coal rents and CO_2 emissions in BRICS countries, and align a path for achieving green growth and sustainable development. Utilizing static panel methodology, the data from the BRICS countries is applied to the proposed panel econometric technique, proceeding first with the OLS, then Panel FE to overcome any statistical limitations.

1.8 Structure of the Study

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

CHAPTER 2: LITERATURE REVIEW

2.1 Analytical Framework

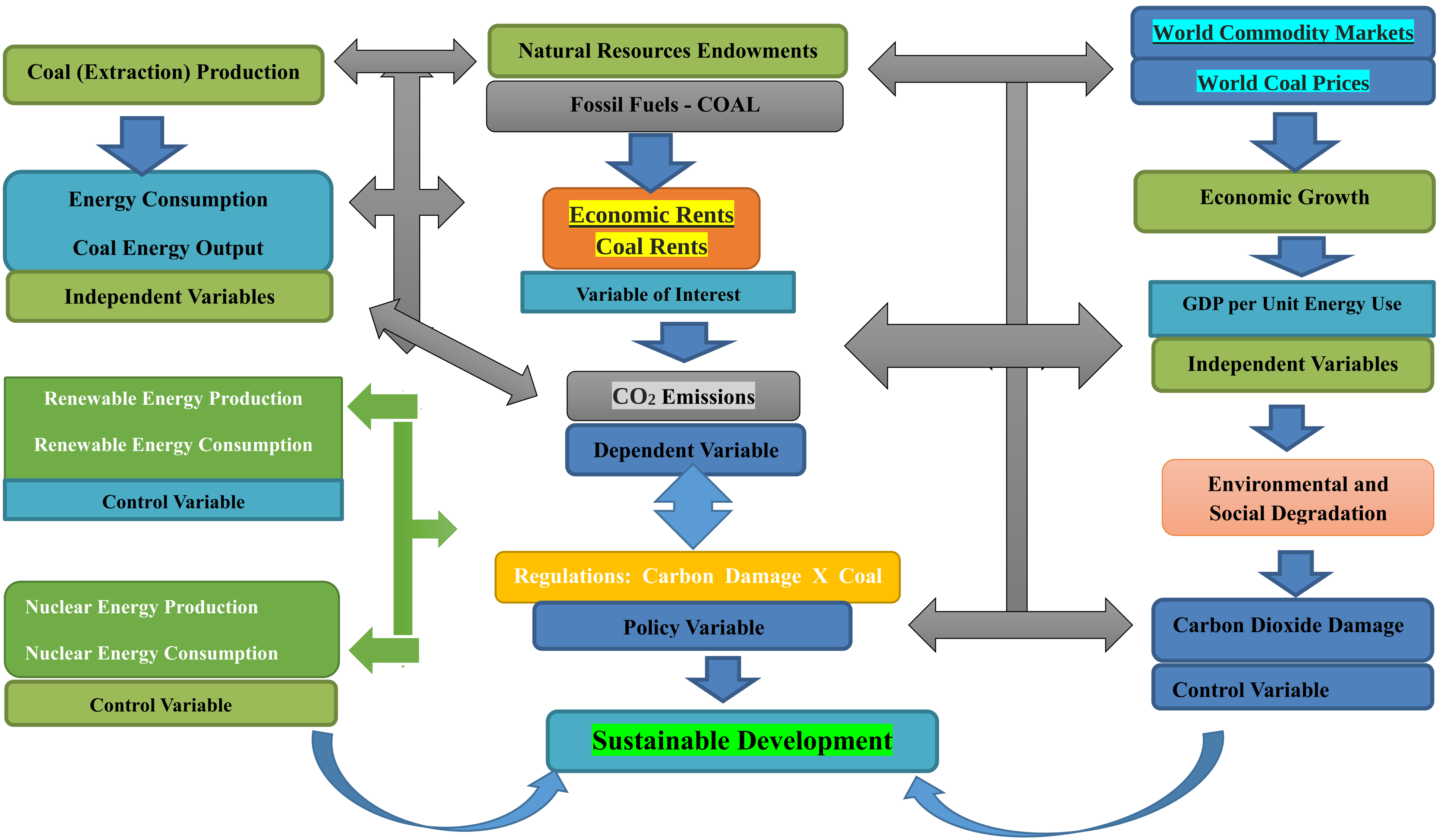
Prior to the review of literature, the analytical framework is presented to outline the conceptual analysis related to economic growth, energy consumption and sustainable development, and their inter-relationship between coal rents and carbon dioxide (CO_2) emissions. Hence, this study focuses on the macro level details and examines the relationship between various dependent variables and the independent variable in order to establish the path to green growth and sustainable development. This assumption is informed by the number of studies that have suggested causality relationships between economic growth, energy consumption and CO_2 emissions (Yoo, 2006; Akinlo, 2008; Odhiambo, 2010; Apergis & Payne, 2010; Cowan, Chang, Inglesi-Lotz & Gupta, 2014). Further studies have also suggested that energy consumption contributes to economic growth, yet has a negative effect on the environment and social well-being, and it is associated to climate change and global warming (Menyah & Wolde-Rufael, 2010; Park & Hong, 2013). This theoretical framework not only presents the independent and dependent variables, but provides the guideline for the detailed literature review of the topic for the study.

The analytical framework (**Figure 1 below**), presents some of the key players in the relationship between energy consumption, economic growth and sustainable development. Respectively, the theoretical framework considers the endowments of natural resources as a source of natural resources rents, which through economic rents; also contribute to economic growth and sustainable development. In case of this study, the natural resources endowments are related to fossil fuels (coal), which provides coal rents (revenues above the cost of extracting the resources) and thus provide incentives for extraction towards coal consumption.

Whereas the incentives from coal rents add value to economic growth, through 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 GDP per unit of energy use often leads to high levels of CO_2 emissions, which are associated to climate change and global warming. In turn, there are externalities to overall objective of sustainable development, which requires a balance between economic development, social inclusion and environmental sustainability. In order to minimize the effects of energy consumption to levels of CO_2 emissions without compromising economic growth, the study suggest the exploitation of renewable energy and nuclear energy consumption, coupled with regulations in form of carbon damage to ensure attaining green growth and sustainable development.

Therefore, the analytical framework guides the study data and methodology to correlate the variables for purposes of establishing the relationships between the dependent and independent variables. Using a different approach from the previous studies, this study considers Carbon Dioxide (CO_2) Emission as the dependent variable, whilst Coal Rents, GDP per Unit of Energy Use, as the independent variables, while "Regulations" (Logarithm of Coal Rent with Carbon Dioxide Damage) as the policy variable. Likewise, control variables are identified to better understand the relationship between coal rents and CO_2 emission, and these include; Nuclear Energy Production, Renewable Energy Production, Coal Production and Carbon Dioxide Damage. In doing so, it is possible to conclusively determine the appropriate mechanism for deriving the relationship between coal rents and CO_2 emission, and establish the requirements for sustainable development.

Figure 1. Analytical Framework



2.2 Background to Literature Review

Energy generating systems tend to generate extensive and severe environmental and social hazards in the process of delivering energy for consumption. In essence, energy is often generated from dirty sources and therefore not ***Clean Energy.*** Adopting greener technologies would minimize the costs of environmental and social degradation but depress financial expansion. The generation of clean energy leads to positive externalities related to ***Green Growth*** and ***Sustainable Development***, thereby reducing the effects to pollution and greenhouse gasses (GHG). The effects to environmental and social degradation like pollution, carbon dioxide (CO_2) emissions, GHG and global warming have been associated with ***non-renewable energy*** sources (Depletable Resources), for example fossil fuels, including coal, natural gas and oil. On the other hand, power generation with little or no significant consequences to climate change and thus not harmful to the environment and social wellbeing, has been associated to ***renewable energy*** sources (Non-Depletable Resources) 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, 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.

The topic of causal links between economic growth, energy consumption and CO_2 emissions has been well-documented in the energy and environmental studies literature. Emphasis has been placed by different researchers on diverse countries, periods, and has applied different research methodologies and proxies to represent the respective variables in an effort to establish causal links. The rest of this chapter presents the review of some of previous studies related to the relationships between economic growth, energy consumption, CO_2 emissions, and other intermittent variables such as, capital, financial development, labor, population, amongst others. Accordingly, this literature review is divided into sub titles to explain the different inter-relationships between the key variables of interest respectively (**Items 5 – 9, refer to Appendix**) with a summary presented in **Table 1** and is thereafter discussed as below;

(1) Energy consumption and economic growth for sustainable development (Energy-Output Nexus, Energy Consumption in General).

(2) Coal consumption and economic growth for sustainable development (Energy-Output Nexus, Coal Consumption in particular).

(3) Economic growth and carbon dioxide (CO_2) emissions for sustainable development (Energy-CO_2 Nexus).

(4) Energy and coal consumption, and environmental and social degradation in general.

(5) Energy and coal consumption, and environmental and social degradation in BRICS.

(6) Energy consumption, CO_2 emissions and environmental and social welfare in BRICS.

(7) Clean Coal Technology and reduction of environmental and social degradations from energy consumption.

(8) Literature review on Policy recommendations for BRICS Countries.

(9) Green Growth and Sustainable Development in BRICS Countries.

2.3 Energy Consumption and Economic Growth for Sustainable Development

Energy is of significant importance in economic growth and is considered a vital driver of sustainable development for most countries across the world. In essence, reliable energy supply is a prerequisite for economic growth, and may yield green growth and sustainable development, thereby creating a balance between economic development, social inclusion and environmental sustainability. Due to its momentous policy implications, the energy consumption-economic growth nexus has become a great concern for policymakers and economists worldwide.

However, most sources of energy, especially fossils like oil or coal; which are an abundant and low-cost resource for many countries, including BRICS countries, contribute to increasing concentration of atmospheric GHGs that negatively impact achieving green growth and sustainable development. According to Ben Amar (2013), energy is a critical input to economic development, an essential part of human activity, and a significant contributor to improving social conditions. However, the use of energy has substantial environmental and social implications, besides the impact to the supply-side of energy.

Therefore, energy supply contribution to economic growth necessitates energy generation systems that deliver clean energy, which create synergies between economic development, social sustainability and environmental sustainability, leading to green growth and sustainable development. In this regard, a number of scholars have argued that certain macro-economic factors coupled with economic growth are determinants of energy consumption and hence it is necessary to apply these variables to forecast energy consumption. Accordingly, to a number of studies that have examined the causal link between economic growth and energy consumption in various countries, suggest a direct correlation and causality between both variables (Yoo, 2006; Odhiambo, 2006; 2010; 2016; Li & Li, 2011; Apergis & Payne, 2010; Menyah & Wolde-Rufael, 2010).

In the African context, Akinlo (2008) using the autoregressive distributed lag (ARDL) bounds test examined the causality between economic growth and energy consumption for eleven (11) countries in sub-Saharan Africa. The empirical results showed that economic growth is correlated to energy consumption in Senegal, Gambia, Sudan, Cameroon, Cote d’Ivoire, Ghana and Zimbabwe. In addition, the study suggested that energy consumption has a significant and positive effect on economic growth in Sudan, Kenya, Ghana and Senegal.

In another study in South Africa, Odhiambo (2009) investigated the relationship between economic growth and electricity consumption, adding employment rates as a sporadic variable for a simple trivariate causality framework using ARDL bounds test approach. The findings showed a two-way causal link of electricity consumption and employment with GDP in South Africa. Odhiambo (2010) further examined causality between economic growth and energy consumption in three (3) Sub-Saharan African countries, namely, South Africa, Kenya and Democratic Republic of Congo (DRC), while incorporating prices as a recurrent variable and using the ARDL methodology. The study findings found a one-way directional causal relationship flowing from energy consumption to economic growth for South Africa and Kenya, while economic growth was the major driver for energy consumption in the DRC.

In other previous papers that involved panel of countries; Yoo (2006) explored the causal relationship between economic growth and electricity consumption among the Association of South East Asian Nations (ASEAN) members, namely, Thailand, Indonesia, Singapore and Malaysia based on data for the period of 1971 to 2002 using the Johansen- Juselius co-integration methodology. The outcomes of the study indicated that there is a bi-directional (two-way) causal relationship between economic growth and electricity consumption in Singapore and Malaysia. The research further showed the presence of uni-directional causal relationship running from economic growth to electricity energy consumption in Thailand and Indonesia. Likewise, Wolde-Rufael (2009) re-investigated the causal links between economic growth and energy consumption for seventeen (17) African countries, adding a multivariate framework of other variables (Capital and Labor). The empirical results showed that in eleven out of the seventeen countries, energy was a more contributing factor to GDP growth, as compared to the contribution of labor and capital. Lastly, Zaidi, Jbir & Gmidene (2014) empirically examined the relationship between energy consumption and real GDP for 19 G-20 economies, using panel data from 1990 to 2010 under Granger-Causality test and Pedroni Panel co-intergration approach. The results of the study confirmed the existence of a long-run relationship between energy consumption and economic activity. In addition, their study revealed the existence of a uni-directional relationship running from electricity and oil consumption to real GDP.

2.4 Coal Consumption and Economic Growth for Sustainable Development

In emphasizing the important inputs of coal energy to economic growth, numerous researchers have studied the causal links between economic growth and coal consumption in many countries, utilizing different research methodologies. In South Africa, for example, Odhiambo (2016) using time-series data, examined the causal links between economic growth and coal consumption during the period from 1980 to 2012 with ARDL bounds approach. The research findings concluded that, there is 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, Yoo (2006) investigated the overall causality in Korea between coal consumption and economic growth by utilizing modern time-series techniques on data for the period of 1968 – 2002 using the ARDL bounds methodology. This research established the bi-directional relationship flowing from coal consumption to economic growth, with coal consumption in Korea increasing by over 3.9% per year.

Furthermore, Li & Li (2011) using data for the period between 1965 and 2006, studied the relationship between GDP and coal consumption in India and China with Granger-causality testing methodology. Their study established that a causal relationship of uni-directional nature exists running from GDP to coal consumption for China, while a similar one-way directional causal relationship running from coal consumption to GDP was for India. In another research for 25

OECD countries, Apergis & Payne (2010) explored the causality between economic growth and coal consumption over the period of 1980 – 2005 with the Granger-causality testing under a multivariate panel framework. The study findings revealed that the causal relationship between economic growth and coal consumption is negative in the short-run and bi-directional. On the other hand, Wassung's (2010) thesis on Water-Energy Nexus in South Africa stipulated that generation of energy requires high quantities of freshwater for cooling, and that the difficult 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.

2.5 Economic Growth and CO_2 Emissions for Sustainable Development

For many decades now, researchers and economists alike have been concerned with how to increase economic growth, while environmentalist on the contrary have been concerned with the increasing environmental and social degradation, as a consequence to CO_2 emissions from economic growth. Hence, this conundrum has driven many studies to investigate the causal relationship between economic growth and CO_2 emissions, and to test the Hypothesis for Environment Kuznet's Curve (EKC), and thereby establish mechanisms of attaining green growth and sustainable development. For instance, Odhiambo (2012) investigated using the ARDL-Bounds testing model the causality between economic growth and CO_2 emissions in South Africa. The results showed that there was a uni-directional causal link flowing from economic growth to CO_2 emissions, while both CO_2 emissions and economic growth are Granger-caused by energy consumption in South Africa. For the OECD and Non-OECD countries, Dinda (2009) using Panel data over the period 1960 – 1990 with Ganger causality test, examined the causal links between economic growth and CO_2 emissions. The results of the study showed that; whereas CO_2 emissions do not lead to increase in economic growth for Non-OECD countries, they were found to increase in economic growth for OECD countries.

In another study for 36 countries, Richmond & Kaufmann (2006) applying time series data studied the causal links between economic growth and CO_2 emissions over the period 1973 – 1997. The study findings revealed no significant causal links between economic growth and CO_2 emissions and thus validated the neutrality of the hypothesis. Similarly in India, Ghosh (2010) using the ARDL testing model and Johansen-Juselius approach, explored the causal relationship between CO_2 emissions and economic growth on time series data between 1971 – 2006, adding additional variables of employment, energy supply and investment. The study findings concluded that the causal links between economic growth and CO2 emissions is bi-directional in the short-run. In addition, the study established causal relationship of uni-directional nature in the short-run, running from energy supply to carbon emissions and economic growth to energy supply.

Furthermore, Sharma (2011) investigated the determinants of CO_2 emissions using a dynamic panel data model for 69 countries categorized on the basis of income into low income, middle income and high income countries from 1985 to 2005. The findings of the study show a positive relationship of GDP per capita, trade openness and energy consumption, while urbanization had a negative relationship with CO_2 emissions for low-income, middle and high-income panels. However, energy consumption and GDP per capita were found to be statistically significant determinants of CO_2 emission. For the Global panel, urbanization, trade openness, energy consumption had a negative effect on the CO_2 emissions. Jaunky (2011) using the Vector Error-Correction Mechanism (VECM), tested the Environment Kuznets Curve (EKC) hypothesis for 36 high-income countries with data for the period between 1980 and 2005. The findings established a short-and long-run uni-directional causal link running from real GDP per capita to per capita CO_2 emissions. Likewise, Saboori, Sulaiman & Mohd (2012) using both VECM and

Granger-Causality test in Malaysia examined causality between economic growth and CO_2 emissions with data for the period 1980 to 2009. The empirical results suggested a long-run relationship between real per capita GDP and per capita CO_2 emissions. Coondoo & Dinda (2006) using the panel unit root test investigated the causal links between income and CO2 emission in 88 countries with time series data for the period from 1960 to 1990. The study findings for all the 88 countries, concluded that a bi-directional causal relationship exist between GDP per capita and per capita CO_2 emissions.

2.6 Energy, Coal Consumption, Environmental and Social Degradation

The causal relatioship between energy, coal consumption and CO_2 emissions or environmental and social degradation has drawn much interest in recent years, with controversial conclusions. Several studies have showed that increasing economic growth, population, urbanization and industrialization are some of the major driving forces behind increased energy use, with a resultant increase in CO_2 emissions. Many countries are finding it difficult to strike a balance between economic development, environmental and social sustainability, and are unable to transform towards green growth and sustainable development. Despite the reported contribution of energy and coal consumption to economic growth, the effects of energy generation to climate change and global warming cannot be undermined as countries move towards green growth and sustainable development. Whereas energy consumption plays a pivotal part in economic growth, the way it is sourced, generated and consumed brings about major shortcomings to environment and social well-being such as pollution, GHGs, and CO_2 emissions.

Accordingly, many studies have examined the environmental and social aspects of energy consumption by exploring the causality between economic growth and CO_2 emissions in a various countries. These studies have examined the correlation between energy consumption and causes of environmental and social degradation, together with determinants of CO_2 emissions as major energy consumption externalities emanate mostly from fossil fuels, such as coal. Menyah & Wolde-Rufael (2010) in South Africa studied causal links between energy consumption, economic growth, and CO_2 emissions in a multivariate framework adding variables of labor and capital for the period between 1965 and 2006. The findings of the study indicated the existence of a causal relationship among the variables of economic growth and CO2 emissions. The study also found a causal relationship of a unidirectional flow from CO_2 emissions to economic growth, and similar for energy consumption to CO_2 emissions, and that of energy consumption to economic growth.

In addition, Park & Hong (2013) analyzed the relationships in South Korea between carbon dioxide (CO_2) emission, economic growth and energy consumption. Although the findings indicated that economic growth and CO_2 emission were unintentional in South Korea, the explanation process of its economic growth and energy consumption showed an important relationship between fossil fuels that emit CO_2, for example coal and economic growth. Similarly, Oh, Wehrmeyer, & Mulugeta (2010) investigated key factors in South Korea that have instigated the fluctuations in patterns of CO_2 emissions for 15 years. The results of the paper showed that the reason why CO_2 emissions increased in South Korea was due to economic growth. In another study for 58 countries, including 3 regional panels (Europe & North Asia, Latin America and Caribbean, Middle East, North Africa, and Sub-Sahara Africa), Saidi & Hammami (2016) investigated the causal links between CO_2 emissions, economic growth and energy consumption with panel data over the period between 1990 and 2012, using dynamic simultaneous-equation. The study findings suggested a causal link of a bi-directional flow between energy consumption and economic growth for the 4 panels, and causal link of a bi-directional flow running from CO_2 emissions to economic growth for the Caribbean and Latin America.

Further studies have probed the causal relationship between economic growth, energy consumption and their impacts on environmental and social degradation by using additional variables. For example in South Africa, Shahbaz, Tiwari & Nasir (2013) explored using time series data for the period between 1965 and 2008, the relationships between trade openness, financial development, coal consumption and economic growth and environment pollution. The paper concluded that economic growth increases the CO_2 emissions levels from energy consumption, and thus consumption of coal has an important contribution to degradation and deterioration of the environment in South Africa. Likewise in Sub-Saharan African countries, Al-Mulali & Binti-Chesab (2013) examined the effect of CO_2 emission and energy consumption on GDP and financial development using a panel data model for period from 1980 to 2008. The findings illustrated that energy consumption positively affected economic growth and financial development, and also has enormous effects on GHGs levels. In case of newly industrialized countries (NIC), Hossain (2011) explored the causality using the Johansen Fisher panel co-integration test between energy consumption, urbanization, CO_2 emissions, economic growth and trade openness with time series data from 1971 to 2007. The study findings indicated causal unidirectional relationship running from trade openness to CO_2 emissions and economic growth. The results further showed causal unidirectional relationships running from trade openness to economic growth, trade openness to urbanization, urbanization to economic growth, and economic growth to energy consumption.

In another research of 6 Sub Saharan African countries: Kenya, Republic of the Congo, Zimbabwe, the DRC (Democratic Republic of the Congo), Zambia and South Africa; Kivyiro & Arminen (2014) studied the causal relationships between FDI, energy consumption, CO_2 emissions and economic growth, with a time series data for the period between 1971 and 2009 using ARDL bounds testing and Granger causality models. The study findings concluded that there is a long-term co-integration relationship between all the variables of the study. Bouznit & Pablo-Romero (2016) analyzed the casual relationship in Algeria between economic growth, energy consumption and CO_2 emissions, adding other variables of exports and imports, with time series data between 1970 and 2010 and using the ARDL bounds testing model. The results of the study indicated that increasing energy consumption would increase CO_2 emissions, while both variables were affected by exports and imports.

2.7 Summary of Literature Review

The literature eviewed is hereby summarized to provide an eagle's view on the various studies and their areas of interest as they relate with energy and coal consumption, economic growth, CO_2emissions, and other added variables for sustainable development in the energy sector **(See Table 1 below)**.

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 (2006)	1971 – 2002	GDP and EC	ASEAN Countries	Johansen-Juselius Model	EC ↔ GDP (SGP & ML)
					Co-Integration Model	GDP ⟶ EC (THL & IDN)
5.	Wolde-Rufael (2009)	1971–2004	GDP and EC	17 African Countries	Granger Causality Test	EC ⟶ GDP
6.	Zaidi, Jbir & Gmidene (2014)	1990 – 2010	GDP and EC	19 G-20 Countries	Granger Causality Test Pedroni Panel Co-Intergration	EC ⟶ GDP
7.	Odhiambo (2016)	1980 – 2012	GDP and CC	South Africa	ARDL Bounds Testing	CC ⟶ EMP
						EG ↔ EMP
8.	Yoo (2006)	1968 – 2002	GDP and CC	South Korea	Co-Integration and Ganger	CC ↔ GDP
9.	Li & Li (2011)	1965 – 2006	GDP and CC	India & China	Co-Integration and Ganger	GDP⟶CC (China)
						CC ⟶ GDP (India)
10.	Apergis & Payne (2010)	1980 – 2005	GDP and CC	25 OECD Countries	Co-Integration/VECM	CC ↔ GDP
11.	Odhiambo (2012)	1970 – 2007	GDP and CO_2	South Africa	ARDL Bounds Testing	GDP ⟶ CO_2
12.	Dinda (2009)	1960 – 1990	GDP and CO_2	OECD/Non–OECD	Ganger causality test	GDP ⟶ CO_2

13.	Richmond & Kaufmann (2006)	1973 – 1997	GDP and CO_2	36 Countries	Co-Integration and Ganger	GDP $\neq$ CO_2
14.	Ghosh (2010)	1971 – 2006	GDP and CO_2	India	ARDL Bounds /VECM	EC $\leftrightarrow$ GDP EC $\rightarrow$ CO_2
15.	Sharma (2011)	1985 – 2005	GDP, TO and CO_2	69 Countries	Dynamic Panel Data Model	TO $\rightarrow$ CO_2 GDP $\rightarrow$ CO_2 EC $\rightarrow$ CO_2
16.	Jaunky (2011)	1980 – 2005	GDP and CO_2	36 Rich Countries	GMM & VECM Models	GDP $\rightarrow$ CO_2
17.	Saboori et al. (2012)	1980 – 2009	GDP and CO_2	Malaysia	ARDL Bounds Testing	CO_2 $\rightarrow$ GDP
18.	Coondoo & Dinda (2006)	1960 – 1990	GDP and CO_2	88 Countries	Co-Integration and Ganger	GDP $\leftrightarrow$ CO_2
19.	Menyah & Wolde-Rufael (2010)	1965-2006	GDP, EC and CO_2 Labor & Capital	South Africa	ARDL and Co-Integration	$CO_{2,}$ $\rightarrow$ GDP EC $\rightarrow$ GDP EC $\rightarrow$ CO_2
20.	Shahbaz et al. (2013)	1963 – 2008	GDP, CC and CO_2 FDI and TO	South Africa	ARDL and Co-Integration	GDP $\rightarrow$ CO_2 CC $\rightarrow$ CO_2
21.	Park & Hong (2013)	1991 – 2011	GDP, EC and CO_2	South Korea	Markov switching model	GDP $\rightarrow$ CO_2 EC $\rightarrow$ CO_2
22.	Oh, Wehrmeyer & Mulugeta (2010)	1990 – 2005	GDP and CO_2	South Korea	Log Mean Divisia index	GDP $\rightarrow$ CO_2
23.	Saidi & Hammani (2016)	1990 – 2012	GDP, EC and CO2	58 Countries	Dynamic Simultaneous	EC $\leftrightarrow$ GDP (4 Panels) $CO_2$$\rightarrow$GDP (LA & CRB)

24.	Al-Mulali & Binti-Chesab (2012)	1980 – 2008	GDP and CO_2 EC and FDI	33 Sub-Saharan	Co-Integration and VECM	EC ⟶ GDP EC ⟶ FDI
25.	Hossain (2011)	1971 – 2007	GDP, EC and CO_2 TO and URBN	NIC	Co-Integration and Ganger Panel Unit Root Tests	GDP ⟶ EC EC ⟶ CO_2
26.	Kivyiro & Arminen (2014)	1971 – 2009	GDP and CO_2 FDI and EC	6 Sub-Sahara Africa	ARDL Bounds Testing	EC ⟶ CO_2 FDI ⟶ CO_2 GDP ⟶ CO_2
27.	Bonznit & Pablo-Romero (2016)	1970 – 2010	GDP, EC and CO_2 Imports & Exports	Algeria	ARDL Bounds Testing	EC ⟶ CO_2
28.	Pao & Tsai (2010)	1971 – 2005	GDP, EC and CO_2	BRIC Countries	Co-Integration and Ganger	EC ↔ CO_2 EC ↔ GDP CO_2 ↔ GDP
29.	Wang, Zhou, Zhou & & Wang (2011)	1995 – 2007	GDP, EC and CO_2	28 Provinces –China	Co-Integration and VECM	GDP ⟶ CO_2 EC ⟶ CO_2
30.	Bloch, Rafiq & Salim (2012)	1965 – 2008	GDP, CC and CO_2	China	Co-Integration and VECM	CC ⟶ GDP CC ⟶ CO_2
31.	Farhani, Shahbaz & Ozturk (2014)	1971 – 2011	GDP, CC and CO_2	China and India	Structural Break Unit Root Co-Integration and VECM	CC ⟶ CO_2 (IND) CC ↔ CO_2 (CHN)
32.	Lin & Wesseh (2014)	1971 – 2010	GDP, EC and EMP	South Africa	Non-Parametric Bootstrap	EC & EMP ⟶ GDP
33.	De Freitas & Kaneko (2011)	1970 – 2009	EC, EMP and CO_2	Brazil	Decomposition approach	GDP ⟶ CO_2

						EMP ⟶ CO_2
34.	Cowan, Chang, Inglesi-Lotz	1990 – 2010	GDP, EC and CO_2	BRICS Countries	Panel Causality Analysis	GDP ↔ CO_2 (RUS)
	Inglesi-Lotz & Gupta (2014)				Panel Bootstrap Method	GDP ⟶ CO_2 (RSA)
						CO_2 ⟶ GDP (BRA)
						GDP ≠ CO_2 (CHN & IND)
						EC ⟶ CO_2 (IND)
						EC ≠ CO_2 (BRA & RSA)
						EC ≠ CO_2 (CHN &RUS)
35.	Govindaraju & Tang (2013)	1965 – 2009	GDP, CC and CO_2	China and India	Co-Integration and Ganger	EC ⟶ CO_2 (CHN & IND)
36.	Pao, Yu & Yang (2011)	1990 – 2007	GDP, EC and CO_2	Russia	Co-Integration and Ganger	GDP ↔ CO_2
						GDP ↔ EC
						EC ↔ CO_2
37.	Pao & Tsai (2011)	1980 – 2007	GDP, FDI and CO_2	BRIC Countries (3)	Panel Co-Integration Model	FDI ↔ CO_2
		1992 – 2007		Russia		GDP ↔ CO_2
						GDP ↔ EC
						GDP ⟶ FDI
						EC ⟶ CO_2
38.	Maryam, Mittal	1991-2011	GDP, EC and CO_2	BRICS Economies	Pooled OLS, Fixed Effects	EC ⟶ CO_2
	& Sharma (2017)				Random Effects	EC ⟶ GDP
39.	Esso & Keho (2016)	1971-2010	GDP, EC and CO_2	12 Sub-Saharan	Co-Integration and Ganger	GDP ↔ CO_2;

EC → CO_2

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, 4 Panels, ARDL, GMM 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 and Vector –Error Correction Model respectively.

CHAPTER 3: METHODOLOGY AND DATA

The advantage of using panel data is that it allows for suitable multilevel or hierarchical modeling to include variables at different levels of analysis, whilst controlling for variables that could not be observed or measured across different settings (Torres-Reyna, 2007). Accordingly, this study utilizes panel data from 1990 to 2015 obtained from WDI 2017, to study the relationship between coal rents and CO_2 in BRICS Countries. Additionally, to meet the second objective of this research study, and thus explore the relationship between coal rents and CO_2 for PSC, with a data-set of 60 countries, selected randomly from the WDI 2017.

Although panel data allows the control of variables, it has drawbacks of heterogeneity and as such, certain methods and tests need balanced panels and cross-country data consistency that could reduce the trade-offs between benefits and shortcomings of using panel data. Based on the objective of this paper, to test the hypothesis stated, the study uses causal inference models with longitudinal data; linear dynamic panel model and static panel data estimator methodology. In this regard, this research study utilized the OLS with pooled data, and then proceeds to apply FE estimation or RE methods depending on the outcome of the Hausman specification test. These three econometric methods are critical in confirming the robustness of the findings across distinct techniques.

Accordingly, the available data of the BRICS and selected panel of countries is applied to the proposed panel econometric technique, proceeding first with OLS estimation methodology. The OLS regression is a generalized linear modelling technique that may be applied to a model, in a multiple or single categorical explanatory variables, which have been appropriately coded or recorded on an interval scale (Hutcheson, 2011). OLS regression methodology is powerful as it is reasonably easier with checking the assumption of the model using simple graphical methods with issues such as linearity, constant variance and the effect of outliers. However, missing values is one major limitation of OLS in the univariate setting even if the assumptions about the covariance structure are correct, as Algorithms for the computation of variance components are not optimal when data are missing. Due to the possibility of cross-sectional dependence that would complicate the analysis of the panel data and the homogeneity assumption, formal tests were performed to evaluate its validity for correct interpretation of results. Therefore, in analyzing the relationship between variables this study proceed to apply Panel FE and RE chronologically to allow making inferences and generalization outside the sample used in the model. In order for the estimated coefficients of the FE models not to be biased, FE model explores the relationship between outcome and predictor variables within an entity and controls for all time-invariant differences between the individual variables. However, RE models assume no correlation between the predictor and entity's error term, which allows for interactions between explanatory variables and time-invariant variables (Torres-Reyna, 2007).

3.1 Empirical Model Specification

Based on the literature review, this research establishes an economic relationship between Coal rents and carbon dioxide (CO_2) emissions in the BRICS countries. From all the variables identified in the literature, the study expects coal rents to outperform the impact of rising per capital growth of GDP, and GDP per Unit of Energy use in the BRICS countries for the period selected. In order to cater for the possibility of heteroscedasticity and raise the confidence level of the findings, two baseline models are specified to examine coal rent's effect on CO_2 Emissions in BRICS countries and answer the hypotheses of the study.

The first model contains coal rents and a set of control variables. This is the baseline model to investigate BRICS economies' specific coal rent effect on CO_2 Emissions and takes the form as specified below;

$$\boldsymbol{EM_{it} = \beta_0 + \beta_1 CR_{it} + \gamma_0 Z_i + \varepsilon_{it}} \quad (1)$$

Where;

$\mathbf{EM_{it}}$ is the Carbon Dioxide (CO_2) Emissions in metric tons of country i in time t.

$\mathbf{CR_{it}}$ is the Coal Rent as a percentage of GDP, of country i in time t.

$\mathbf{Z_{it}}$ is a vector of other controls, believed to influence the dependent variable (CO_2 emissions). The coefficients β_0 and β_1 are the parameters of interest, and γ_0 captures the effects of the control variables in Z_i. The control variables consist of Nuclear Energy Production, Renewable Energy Production and GDP per Unit of Energy Use.

$\boldsymbol{\varepsilon it}$ is the error term over time.

The above model could be explained in full terms; where CO_2 emissions is the dependent variable (EM), which defines the country's drive towards achieving green growth and sustainable development. CR is the Coal Rent and Z_i is a vector of other economic control variables believed to influence CO_2 Emissions. The control variables consist of Nuclear Energy Production (% of Total), Renewable Energy production (% of Total), and GDP per unit of Energy use ($/kg of Oil), γ_0 is a vector of coefficient estimates of the control variables, i= 1,….., N and t = 1,….., T are correspondingly the distinct and temporal magnitudes of the panel, β_i is the country fixed effects and ε_{it} is an idiosyncratic error term.

3.1.1 Pre-Estimation

In this research study, the summary statistics of the variables used, scatter plot of these variables, descriptive statistics as well correlation matrix of the variables are presented. The study proceed to test for heteroscedasticity, and to decide on whether to use the fixed effects or random effects estimation techniques, following the Hausman specification test. Finally, the study carried out the test for Instrument Relevance, so as to apply the right and valid instrumental variable for unbiased hypothesis testing.

3.1.2 Estimation

For data analysis, a simple strategy would be to estimate the model in equation (1) and (2) using OLS model regression. However, there could be problems associated with this approach. According to Antonakis, Bendahan, Jacquart & Lalive (2014), two of these problems include statistical endogeneity problems which may be due to the capturing of reverse causality issue or the effect of some of the omitted variables (e.g., geographical characteristics, culture and so on), and the possibility of measurement error of our variables of interest (which are CO_2 emissions and coal rents in case of this study). The abovementioned errors often become a burden to other variables, leading to a possibility of upward or downward biases. Hence, if not corrected, these two problems will yield OLS estimates that do not correspond to the causal relationship or effect the variables of interests for this study (Coal rents on CO_2 emissions).

Subsequently, the study engages the next strategy of either to apply the fixed effects or random effects panel data model. This statistical model is soundly effective to figure out the causes of changes within a sample as the regressors could be allowed to either correlate or not correlate with the individual effects. Based upon the standard Hausman test, most studies in economics for many years have selected between RE and FE estimators models (Baltagi, Bresson & Pirotte, 2003). The FE or RE model would be able to control for all time-invariant differences between the data-set for BRICS and PSE economies, so that the estimated coefficients are unbiased due to the omitted time-invariant characteristics such as coal usage policies, carbon damage or changes, renewable energy structures, amongst others.

Accordingly, as all the variables are time-invariant, this model could be appropriate to establish a causal effect of coal rents on CO_2 emissions in BRICS economies or the selected economies of the 60 countries (**PSC**). The choice of the 60 countries is motivated by the availability of data from WDI 2017 in respect to the variable of interest (Coal rents and CO_2 emissions). This causal effect could be examined based on the regression equation below;

$$\boldsymbol{EM_{it} = \beta_i + \beta_1 CR_{it} + \gamma_0 Z_{it} + \varepsilon_{it}} \qquad \textbf{(2)}$$

Where the dependent variable EM_{it} stands for CO_2 Emissions of country **i** in period **t**. $\mathbf{CR}_{it}$ is the main variable of interest, and it is country **i**'s Coal Rents in period t. $\mathbf{B_i}$ represents the country fixed-effect and $\mathbf{Z_{it}}$ is a set of other control variables that includes; GDP per Unit of Energy Use, Renewable Energy Production and Nuclear Energy Production, and ε_{it} stands for the error term.

Despite the fact that the fixed or random effects techniques can solve individual as well as time effects and can adjust for heteroscedasticity, and they seem plausible compared to pooled OLS estimation model, they generally need certain assumptions to be fulfilled, for instance, the strict exogeneity assumption. Thus, the shortcomings of RE and FE is that they are centered on country-specific effects and do not consider for stationarity, dynamics and endogeneity. Whereas FE and RE estimators bring about substantial bias and thus, may yield misleading inferences even when there is no correlation between the regresors and individual effects. The inconsistency of OLS is mainly due to endogeneity. (Baltagi, Bresson & Pirotte, 2003).

3.2 Definition and Description of Variables

As mentioned previously, the dependent variable is CO_2 emissions to interact with Coal Rents and other independent variables utilizing the baseline model as outlined in the estimation process. In addition, coal rents is interacted with carbon dioxide damage to derive at the policy variable of regulations. The control variables are Nuclear Energy Output, Renewable Energy Output, Coal Energy Output and GDP per Unit of Energy Use. **Tables 2** below further presents the full details of the definition and description of the variables and **Tables 3** and **4** presents the summary of descriptive statistics for BRICS and PSC. In order to control the challenges of heteroscedasticity, all variables have been transformed into natural logarithm form.

Table 2: Descriptions and Definitions of Variables

Category	**Measured by**	**Definition**
Outcome Variable (***Dependent Variable***)	CO_2 Emissions – **EM**	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.
Policy Variable	Regulations	Regulations are restrictions and laws putting a price on CO_2 emissions and how to address climate change from concern to action. In this study, Regulations are derived from interactions between the Log of Coal Rents (% of GDP) and Carbon Dioxide Damage (% of GNI).
Independent Variables	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.
Control Variables	Nuclear Energy Production (% of Total)	Nuclear power refers to electricity produced by nuclear power plants. Sources of electricity refer to the inputs used to generate electricity.

Category	Measured by	Definition
	Renewable Energy Production (% of Total)	Renewable energy production is the share of renewable energy in total final energy produced in the country.
	GDP per Unit of Energy use ($/kg of Oil)	GDP per unit of energy use is the PPP GDP per kilogram of oil equivalent of energy use. PPP GDP is gross domestic product converted to 2011 constant international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as a U.S. dollar has in the United States.

Table 3: Summary of Descriptive Statistics – BRICS

Variables	Log	Obs	Mean	Std. Dev.	Min	Max
Country		0				
CC		130	3	1.419684	1	5
Year		130	2002.5	7.529014	1990	2015
Renewable Energy Consumption **(% of Total Energy Consumption)**	**REC**	130	27.93605	17.62846	3.227796	58.65286
Renewable Energy Production **(% of Total Energy Output)**	**REP**	130	28.20386	30.74614	0.084217	95.40534
Nuclear Energy Production **(% of Total Energy Output**)	**NEP**	130	5.203384	5.058335	0.021151	17.71876
Coal Rents **(% of GDP)**	**CR**	130	1.023846	1.198488	0.0000162	7.851874
Coal Energy Production **(% of Total Energy Output)**	**CEP**	130	51.773590	35.588730	1.934310	95.730870
CO_2 Emissions **(kilotons)**	**CO2**	130	2000776	2872855	208887	21100000
CO_2 Emissions Per Capita **(Metric Tons per capita)**	**CO2PC**	130	5.569011	4.260187	0.71118	14.88765
Carbon Dioxide Damage **(% of GNI)**	**CDofGNI**	130	3.223905	1.888572	0.348209	11.19045
GDP Per Unit of Energy Use **(Constant 2011 PPP $ per kg oil Equivalent)**	**RGDPEU**	130	5.879558	2.75558	1.990115	11.15509

Source: Author's Compilation

Table 4: Summary of Descriptive Statistics – PSC

Variables	Log	Obs	Mean	Std. Dev.	Min	Max
Country		0				
CC		1,560	30.5	17.32366	1	60
Year		1,560	2002.5	7.502405	1990	2015
Renewable Energy Consumption **(% of Total Energy Consumption)**	**REC**	1,560	26.54892	26.16838	0.43839	95.17764
Renewable Energy Production **(% of Total Energy Output)**	**REP**	1,560	35.75199	31.781	0	100
Nuclear Energy Production **(% of Total Energy Output)**	**NEP**	1,560	10.10923	18.06964	0	79.5118
Coal Rents **(% of GDP)**	**CR**	1,560	0.283462	1.080265	0	22.93441
Coal Energy Production **(% of Total Energy Output)**	**CEP**	1,560	26.13462	26.86829	0	100.0836
CO_2 Emissions **(kilotons)**	**CO2**	1,560	247369.4	703141.2	132.012	5795162
CO_2 Emissions Per Capita **(Metric Tons per capita)**	**CO2PC**	1,560	5.439765	4.395974	0.050069	20.33194
Carbon Dioxide Damage **(% of GNI)**	**CDofGNI**	1,560	1.785934	2.281124	0.097653	21.4244
GDP Per Unit of Energy Use **(Constant 2011 PPP $ per kg oil Equivalent)**	**RGDPEU**	1,560	7.852747	3.362368	0.83511	21.49684

Source: Author's Compilation

3.3 Expected Results

Given the models specified in equations above, the variables' expected coefficient results are presented in Table 5 as follows:

Table 5: Summary of Expected Coefficient Results of the Study

Variable	Expected Sign
Coal Rents	Positive
Nuclear Energy Production (% of Total)	Negative
Renewable Energy production (% of Total)	Negative
Coal Energy Production (% of Energy Total)	Positive
GDP per Unit of Energy use ($/kg of Oil)	Positive
Regulations	Negative

3.4 The Data and Sources

This research study utilized two panel data-sets, separately analyzed; 1st for the 5 BRICS economies and the 2nd from made-up of a sample of sixty (60) economies composed of developing and developed nations (**Appendix 14**). The PSC data-set is made-up of 60 economies and was randomly selected based on the availability of data in respect to the key variables of interest for the period 1990 to 2015 from the WDI 2017. The major motivation for adding the PSC was to make a comparative analysis of the effects of regulations quality to reducing CO_2 emissions for sustainable development.

CHAPTER 4: RESULTS AND DISCUSIONS

4.1. Pre-Estimation Tests

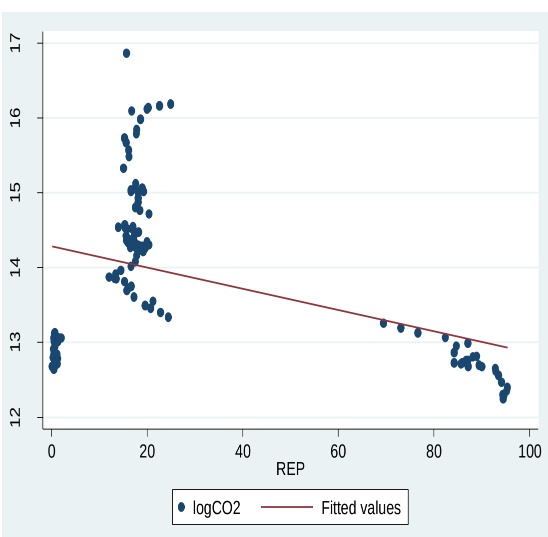
This section provides a detailed account of the findings obtained from employing pooled OLS and FE per econometric equations as stipulated in the empirical models. Data analysis commenced with pooled OLS and FE for the BRICS, and thereafter for PSC. Therefore, the results of the pre-estimate tests commence with scatter plots to present statistical relationship and correlations, and possible causation and dependence between the key variables. The Scatter plots are run initially for BRICS countries and then PSC, as presented in the Scatter Plots **Figures 2 – 6** (**BRICS**) and **7 – 11** (**PSC**) respectively.

Scatter plots presented in **Figures 2 – 11** below summarize the relationship and correlation in respect to BRICS economies for the following variables; (i) CO_2 emissions and Renewable Energy Output, (ii) CO_2 emissions and Nuclear Energy Output, (iii) CO_2 emissions and Coal Rents,

(iv) CO_2 emissions and Coal Energy Output, and (v) CO_2 emissions and GDP per Unit of Energy use. The pre-estimation results illustrate a positive-medium to strong correlation for CO_2 emissions with Coal Rents, Coal Energy Output and GDP per Unit of Energy use, while a negative-strong correlation is observed for CO_2 emissions with Renewable Energy Output and Nuclear Energy Output. The above observations are significantly aligned with the expected results, and statistically emphasize that coal rents, coal energy output and GDP per unit of Energy use have a positive effect to or relationship with CO_2 emissions in BRICS. In addition, the pre-estimation results illustrate that Renewable Energy Output and Nuclear Energy Output have a negative effect to CO_2 emissions in BRICS countries

Figure 2: Scatter Plot - BRICS

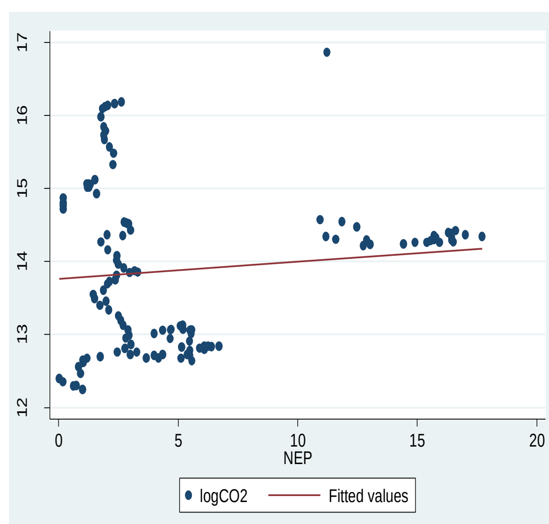
Relationship between CO_2 Emissions and REP



Source: Author's Compilation

Figure 3: Scatter Plot – BRICS

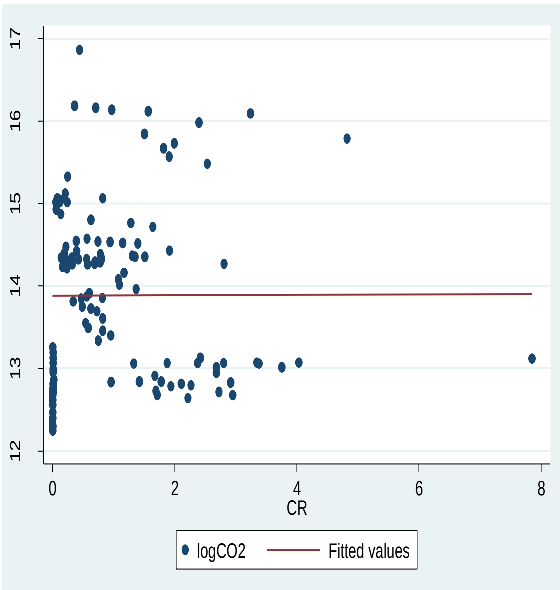
Relationship between CO_2 Emissions and NEP



Source: Author's Compilation

Figure 4: Scatter Plot – BRICS

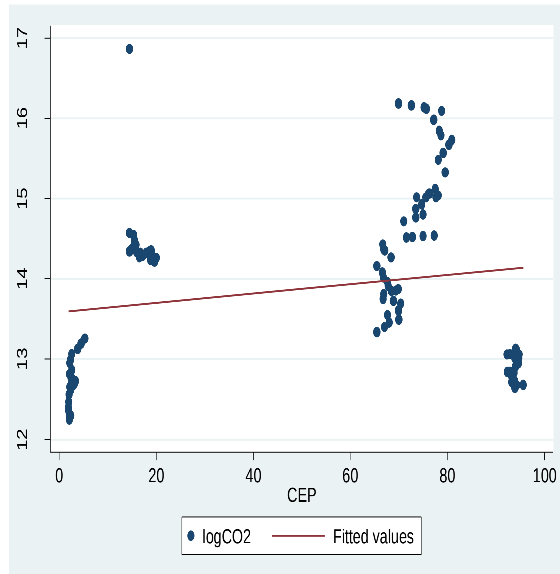
Relationship between CO_2 Emissions and CR



Source: Author's Compilation

Figure 5: Scatter Plot – BRICS

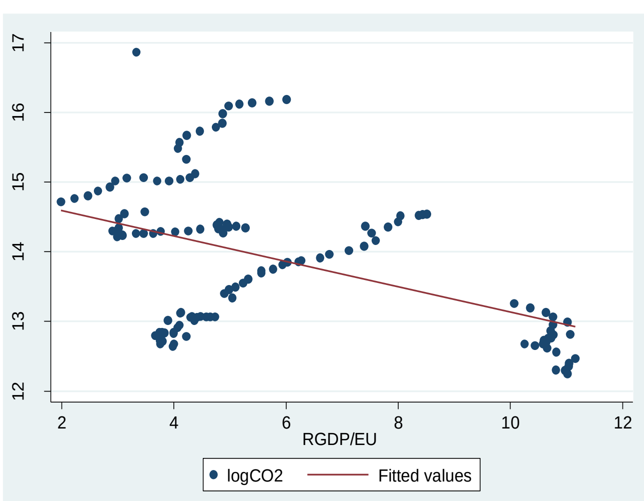
Relationship between CO_2 Emissions and CEP



Source: Author's Compilation

Figure 6: Scatter Plot – BRICS

Relationship between CO_2 Emissions and RGDPEU

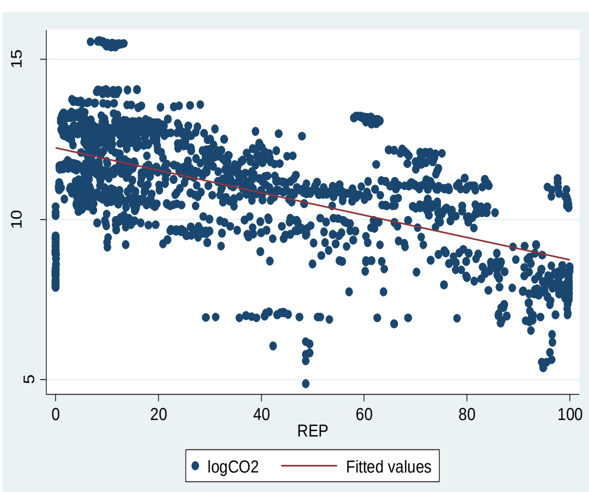


Source: Author's Compilation

Likewise, Scatter plots presented in **Figures 7 – 11** below summarize the relationship and correlation in respect to the PSC for the following variables; (i) CO_2 emissions and Renewable Energy Output, (ii) CO_2 emissions and Nuclear Energy Output, (iii) CO_2 emissions and Coal Rents, (iv) CO_2 emissions and Coal Energy Output, and (v) CO_2 emissions and GDP per Unit of Energy use. The pre-estimation results illustrate a positive-medium correlation for CO_2 emissions with Coal Rents, Coal Energy Output and GDP per Unit of Energy use, while a negative-strong correlation is observed for CO_2 emissions with Renewable Energy Output and Nuclear Energy Output. The above observations are significantly aligned with the expected results, and statistically emphasize that coal rents, coal energy output and GDP per unit of Energy use have a positive effect to CO_2 emissions in the PSC. In addition, the pre-estimation results illustrate that Renewable Energy Output and Nuclear Energy Output have a negative effect to CO_2 emissions in PSC.

Figure 7: Scatter Plot – PSC

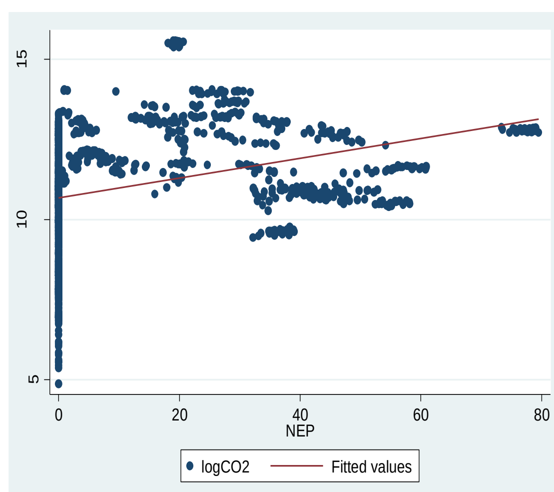
Relationship between CO_2 Emissions and REP



Source: Author's Compilation

Figure 8: Scatter Plot – PSC

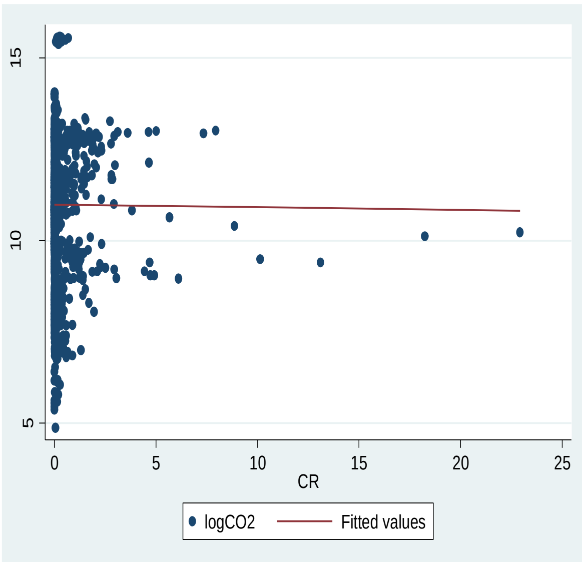
Relationship between CO_2 Emissions and NEP



Source: Author's Compilation

Figure 9: Scatter Plot – PSC

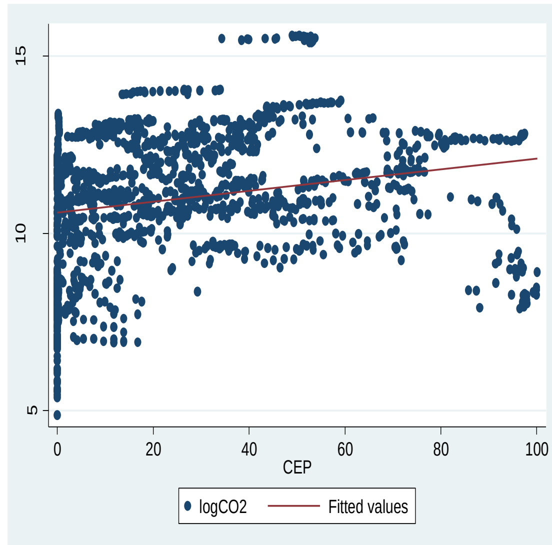
Relationship between CO_2 Emissions and CR



Source: Author's Compilation

Figure 10: Scatter Plot – PSC

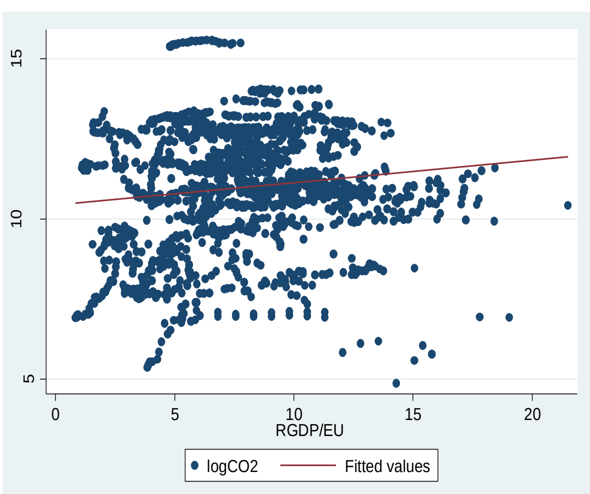
Relationship between CO_2 Emissions and CEP



Source: Author's Compilation

Figure 11: Scatter Plot – PSC

Relationship between CO_2 Emissions and RGDPEU



Source: Author's Compilation

Consequent to the above correlations between variables, the study analysis explores correlation coefficients for purposes of statistically determining the degree and linearity of the relationship between the variables. In this regard, the Pearson's correlation coefficients are presented in **Table 6** (**BRICS**) and **Table 7** (**PSC**) to explain the linear correlation between variables respectively. Using the Pearson's correlation coefficients, the study further provides explanation of the relationship and correlation between the interactions of variables as earlier presented in Scatter Plots under **Figures 2 – 11**. This seeks to validate results of scatter plots and provide the required statistical evidence to strengthen the acceptance or rejection of hypotheses.

Table 6: Pearson's Correlation Matrix – BRICS

		logCO2	**REP**	**NEP**	**CR**	**CEP**	**RGDPEU**
Log CO_2 Emissions (kt)	**logCO2**	1.0000					
Renewable Energy Production **(% of Total Energy Output)**	**REP**	-0.4087*	1.0000				
		0.0000					
Nuclear Energy Production **(% of Total Energy Output**)	**NEP**	0.1109	-0.2919*	1.0000			
		0.2091	0.0008				
Coal Rents **(% of GDP)**	**CR**	0.0025	-0.5341*	-0.0783	1.0000		
		0.9777	0.0000	0.3758			
Coal Energy Production **(% of Total Energy Output)**	**CEP**	0.1928*	-0.7661*	-0.3423*	0.6520*	1.0000	
		0.028	0.0000	0.0001	0.0000		
GDP Per Unit of Energy Use **(Constant 2011 PPP $ per kg oil Equivalent**	**RGDPEU**	-0.4694*	0.8739*	-0.3853*	-0.3599*	-0.5704*	1.0000
		0.0000	0.0000	0.0000	0.0000	0.0000	

Source: Author's Compilation

In respect to the BRICS countries, the linear relationship and correlation between the variables as illustrated in the scatter plots could be confirmed using the Pearson's correlation coefficients as presented in **Table 6** above. The Pearson correlation product-moment correlation coefficients shows the positive-weak correlation between CO_2 emissions with Coal rents **(0.0025)**, Coal Energy Output **(0.1928)**, while a negative-medium to strong correlation is confirmed between

CO_2 emissions with Renewable Energy Output **(-0.4087)** and GDP per unit of Energy use **(-0.0494)**. Similar to scatter plots' observation of plots to lie slightly closer to the line of best fit, these observations are demonstrated by the closeness to 1 of most of the correlation coefficients, suggesting valid linear relationships between CO_2 emissions with the variables of interest. In particular, the positive correlation between CO_2 emissions with Coal rents **(0.0025)** and Coal Energy Output **(0.1928)**, implies that more coal rents motivates exploitation of coal for coal energy output or exports, which increases the levels of CO_2 emissions in BRICS economies. While the negative correlation between CO_2 emissions with Renewable Energy Output **(-0.4087)**, implies that more renewable energy output would lead to reduction in levels of CO_2 emissions for BRICS economies. The above observations are consistent with previous studies in the literature, which highlight that higher coal energy use results into CO_2 emissions and thus would negatively affect sustainable development.

Table 7: Pearson's Correlation Matrix – PSC

		logCO2	**REP**	**NEP**	**CR**	**CEP**	**RGDPEU**
Log CO_2 Emissions (kt)	**logCO2**	1.0000					
Renewable Energy Production **(% of Total Energy Output)**	**REP**	0.5970*	1.0000				
		0.0000					
Nuclear Energy Production **(% of Total Energy Output**)	**NEP**	0.3009*	0.3599*				
		0.0000	0.0000				
Coal Rents **(% of GDP)**	**CR**	-0.0045	0.1222*	0.0705*	1.0000		
		0.8599	0.0000	0.0053			
Coal Energy Production **(% of Total Energy Output)**	**CEP**	0.2201*	0.5908*	0.0003	0.2983*	1.0000	
		0.0000	0.0000	0.9903	0.0000		
GDP Per Unit of Energy Use **(Constant 2011 PPP $ per kg oil Equivalent**	**RGDPEU**	-0.1262*	0.0670*	0.1482*	0.1328*	-0.0411	1.0000
		0.0081		0.0000	0.0000	0.0000	0.1042

Source: Author's Compilation

As regards to the PSC, the linear relationship and correlation between the variables as illustrated in the scatter plots could be confirmed using the Pearson's correlation coefficients as presented in **Table 6** above. On the contrary to the scatter plots, the Pearson correlation product-moment correlation coefficients show mixed results. They contradictorily illustrate positive-medium to strong correlation between CO_2 emissions with Renewable Energy Output **(0.5970)**, Nuclear Energy Output **(0.3009)**, Coal Energy Output **(0.2201)**, while a negative-medium to strong correlation is seen between CO_2 emissions with Coal Rents **(-0.0045)** and GDP per unit of Energy use **(-0.1262)**. Although these observations are demonstrate the closeness to 1 for most of the correlation coefficients suggesting valid linear relationships between CO_2 emissions with the variables of interest, there is a need to further run the regression prior to interpretation of their significance to the study hypotheses.

4.2. Cross-Country Dependence Tests

Initially, cross-country dependence was tested on both the panel of countries and BRICS countries for purposes of eliminating any errors and ensures robustness of results. In the case of the panel of all countries, test of Cross-Sectional Dependency across countries was carried out and yielded the results in **Table 8** below. Since the p-value is less than 0.05, then it could be concluded that the panel macroeconomic dataset consists of cross-country dependency, and hence we make use of standard errors that are robust to cross-dependency and heteroscedasticity of unknown form. In the case of BRICS countries, results indicated that the p-value is higher than 0.05 (See **Table 8 below**). Hence conclude that the panel macroeconomic dataset does not consist of cross-country dependency. Accordingly, the research simply makes use of robust standard errors to control for heteroscedasticity of unknown form.

Table 8: Cross-Country Dependence Tests

	BRICS	PSC
Pesaran's test of Cross Sectional Independence =	**-0.264; Pr = 0.7916**	**41.119; Pr = 0.0000**
Average absolute value of the off-diagonal Elements	**0.18**	**0.412**

Source: Author's Compilation

4.3. Hausman Specification Tests

The Hausman specification test was carried out on both BRICS and the PSC combined data-set to eliminate endogeneity concerns in the regression model. The results of the Hausman specification test are presented in **Table 9** at 5% level of significance. Since Prob > chi2 is less than 5% level of significance, for both BRICS and PSC; the study utilize the FE estimations technique to control for individual time and country-specific effects.

Table 9: Hausman Specification Test – BRICS and PSC

		Coefficients ----			
		(b)	**(B)**	**(b-B)**	**sqrt(diag (V_b-V_B))**
		fe	**re**	**Difference**	**S.E.**
Coal Rents **(% of GDP)**	**CR**	.0137439	-.2094141	.2231579	.
Renewable Energy Production **(% of Total Energy Output)**	**REP**	-.0418763	.0046626	-.0465389	.
Nuclear Energy Production **(% of Total Energy Output**)	**NEP**	-.1288608	-.1363325	.0074717	.
CEP Coal Energy Production **(% of Total Energy Output)**	**CEP**	-.0186976	-.0276164	.0089188	.0111421
GDP Per Unit of Energy Use **(Constant 2011 PPP $ per kg oil Equivalent**	**RGDPEU**	.2799204	- .212982	.4929025	.
Regulations **(CD x CR)**	**logCD_CR**	.0642984	.3902156	-.3259173	.
		b = consistent under Ho and Ha; obtained from xtreg			
	B =	inconsistent under Ha, efficient under Ho; obtained from xtreg			
	Test: Ho:	difference in coefficients not systematic			
		chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 1,853.19			
(V_b-V_B is not positive definite)		**Prob>chi2 = 0.0000**			

Source: Author's Compilation

4.4. Estimation of Results

The general empirical results from regressions established on a data sample for BRICS countries are presented in Figure 12. Using the regression model in all regression as indicated in the estimation (**$EM_{it} = \beta_0 + \beta_1 CR_{it} + \gamma_0 Z_i + \varepsilon_{it}$**), the independent variable CO_2 emissions is converted to logarithm to investigate the relationship between the dependent variables. In addition, to establish the regulations – policy variable, an interaction of coal rents and carbon dioxide damage (logCD_CR) is utilized in this respect.

Figure 12: Estimation Results of CO_2 Emissions – BRICS

Dependent Variable = logCO2		
	Pooled OLS	Fixed Effects
CR	-0.209	0.081
	(2.98)***	(1.65) **
REP	0.005	-0.033
	(0.39)	(3.38)**
NEP	-0.136	-0.148
	(3.99)***	(5.11)***
CEP	0.028	0.038**
	(3.26)**	(1.90)
RGDPEU	-0.213	0.230
	(5.91)***	(4.31)***
logCD_CR	0.390	0.102
	(6.66)***	(3.09)**
_cons	9.018	13.047
	(4.60)***	(12.39)***
R^2	0.74	0.63
N	130	130

Robust Standard Errors in parenthesis * *p*<0.05; ** *p*<0.01, *** p<0.001

Fixed Effects method is preferred for estimation of the CO_2 emissions equation based on the Hausman test **(Prob> Chi^2 = 0.000)**.

Source: Author's Compilation

The results of the empirical regression model for the BRICS countries in **Figure 12** above are consistent with the empirical evidence documented in the literature, and with the expected results of this research, albeit at different significance levels. Coal rents are positive and relatively significant at 1% level in FE model, with coefficient of **0.081**. The positive coefficient implies that a **1%** increase in coal rents will increase CO_2 emissions by **0.081%** in BRICS countries. Also, renewable energy output is negative and highly significant at 99.9% in FE model, with coefficient of **-0.033**. Accordingly, the negative coefficient implies a 1% increase in renewable energy output will reduce CO_2 emissions by **0.033%** in BRICS countries. Nuclear energy output was found to be highly statistically significant at 99.9% in both pooled OLS and FE regression models, with coefficients of **-0.136** and **-0.148** respectively. The variable is negative and highly statistically significant at 99.9% in pooled OLS and at 1% level in FE model. This negative sign implies that a **1%** increase in renewable energy output would reduce CO_2 emissions by **0.148%**, thereby encourage the drive to achieve sustainable development in BRICS countries.

In addition, coal energy output is positive and statistically significant at 1% level in FE model, with coefficient of **0.038**. Accordingly, the positive coefficient implies that a 1% increase in coal energy output may increase CO_2 emissions by **0.038%** in BRICS countries. Secondly, GDP per Energy Use is positive at 1% in both pooled OLS and FE regression models, with coefficients of **0.390** and **0.230** respectively. These positive coefficients imply that a **1%** increase in GDP per Energy Use will increase CO_2 emissions by **0.230%** in BRICS countries. Lastly, regulations (log interactions between coal rents and CO_2 damage) was found to be positive and statistically significant at 1% in both pooled OLS and FE regression models, with coefficients of **0.390** and **0.102** respectively. As a result, the positive coefficients imply that instituting regulations to coal consumption may not have significant effect to reduction in levels of CO_2 emissions for BRICS economies. The regulations may further negatively affect the BRICS efforts for achieving green growth and sustainable development.

Figure 13: Estimation Results of CO_2 Emissions – PSC

Dependent Variable = logCO2		
	Pooled OLS	Fixed Effects
CR	-0.222	0.023
	(4.10)**	(3.46)**
REP	-0.034	-0.016
	(26.31)**	(17.67)**
NEP	0.007	-0.008
	(3.69)**	(4.01)**
CEP	-0.022	0.003
	(11.67)**	(3.45)**
RGDPEU	0.099	0.057
	(8.63)**	(10.22)**
logCD_CR	0.264	0.042
	(20.45)**	(10.40)**
_cons	7.874	10.996
	(33.31)**	(109.35)**
R^2	0.60	0.57
N	1,408	1,408

Robust Standard Errors in parenthesis * *p*<0.05; ** *p*<0.01, *** p<0.001

Fixed Effects method is preferred for estimation of the CO2 emissions equation based on the Hausman test (**Prob> Chi2 = 0.000).**

Source: Author's Compilation

Similarly, Figure 12 above presents the results of the empirical regression model for the PSC. Although at different significance levels; the results are similar to the BRICS countries, and thus consistent with the empirical evidence documented in the literature and with the expected results of this research. The variable of interest, Coal rent, is relatively significant and positive at 1% level in FE model, with coefficient of **0.023**. Therefore, the positive coefficient of coal rent implies that a **1%** increase in coal rents will increase CO_2 emissions by **0.023%** for PSC. Secondly, renewable energy output is significant and negative at 1% level in both Pooled OLS and FE models, with coefficient of **-0.034 and -0.016** respectively. The negative coefficient implies that, a 1% increase in renewable energy output will reduce CO_2 emissions by **0.016%** in PSC. Thirdly, nuclear energy output was found to be negative and statistically significant at 1% in FE regression model, with coefficients of **-0.008**. The result of a negative sign implies that a **1%** increase in renewable energy output would reduce CO_2 emissions by **0.008%**, and would allow PSC to accelerate their efforts towards sustainable development.

Furthermore, coal energy output is positive and statistically significant at 1% level in FE model, with coefficient of **0.003**. Consequently, the positive coefficient implies that a 1% increase in coal energy output may increase CO_2 emissions by **0.003%** in PSC. GDP per Energy Use was found to be positive at 1% in both pooled OLS and FE regression models, with coefficients of **0.099** and **0.057** respectively. These positive coefficients imply that a **1%** increase in GDP per Energy Use will increase CO_2 emissions by **0.057%** in PSC. Regulations (interactions log between coal rents and CO_2 damage) was found to be positive and statistically significant at 1% in both pooled OLS and FE regression models, with coefficients of **0.264** and **0.042** respectively. Accordingly, the positive coefficients imply that instituting regulations to coal consumption have no effect to reducing the levels of CO_2 emissions in PSC, and would further negate their efforts for achieving green growth and sustainable development.

CHAPTER 5: SUMMARY AND CONCULUSION

5.1 Summary of the Study

The main objectives of this research were to examine the existence of a relationship between coal rents and CO_2 emissions in BRICS countries, and later extend research investigations to the PSC of sixty (60) nations **(Appendix 1)**. The total of sixty (60) nations has been randomly selected based on these economies' dependency on coal consumption for energy output and availability of data for the variable of interest (Coal Rents) as obtained from WDI 2017. While there is abundant literature on energy consumption and economic growth vis-a-vis BRICS countries and the rest of nations, there is little research investigating the causal relationship between coal rents and CO_2 emissions, and utilizing the two models of pooled OLS and FE estimation models. Using the econometric estimation model of $\boldsymbol{EM_{it} = \beta_0 + \beta_1 CR_{it} + \gamma_0 Z_i + \varepsilon_{it}}$**;** the study attempted to deliver estimation results, with statistical significance in order to establish the criteria for either accept or reject the four (4) research hypotheses.

Based on the expected results prior to the empirical analysis, overall, the study met its main objectives of investigating the relationship between coal rents and CO_2 emissions for the 5 BRICS countries and PSC using data-set from 1990 to 2015 and utilizing the two (2) methodologies of pooled OLS and FE estimation. Although the study did not have many previous studies with similar variables of interest and methodologies, it built on the strengths of the studies like those of Saidi & Hammani (2016), Maryam, Mittal & Sharma, (2017) by focusing the analysis to BRICS and PSC. These studies together with the literature on the application of the pooled OLS and FE estimation regression models, for example by Baltagi, Bresson, & Pirotte, (2003) and Hutcheson, (2011), where useful in attempting to overcome the shortcomings of studies that make use of the above-mentioned methodology and panel data-set in order to make informed conclusions.

During the empirical analysis, the possibility of endogeneity, simultaneity bias and unobserved heterogeneity of the variables of interest (coal rents) were minimized by using a two-phase approach analysis of data, moving from pooled OLS to FE after testing for cross-country dependence and performing the Hausman Specification test. Overall, the estimation results illustrate that in BRICS countries, coal rents have a statistically significant and positive relationship with CO_2 emissions and thus the increase in coal rents will increase CO_2 emissions, and frustrate efforts towards sustainable development. In addition, the estimation results in BRICS for coal energy output show a positive and statistically positive correlation with CO_2 emissions, implying that an increase in coal energy consumption would increase levels of CO_2 emissions.

Equally, the results of the estimation for renewable energy output and nuclear energy output for BRICS countries 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 of CO_2 emission levels in BRICS countries. Finally, the study interacted coal rents and carbon dioxide damage to create a Policy Variable (**Regulations**). The estimation results outline that the relationship between regulations and CO_2 emissions is positive and statistically significant for both BRICS and PSC. Accordingly, the above estimation finding prove that imposing regulations to coal consumption in form of CO_2 damage costs or charges (Taxes and Fines) may have little or no effect in reducing CO_2 emissions in both BRICS and PSC, and could harm efforts to achieve sustainable development.

5.2 Policy Recommendations

The research findings suggest that there is a statistically significant and positive relationship between coal rents and CO_2 emissions in BRICS countries. In addition, the study suggest that coal energy output has a positive and statically significant relationship with CO_2 emissions in BRICS economies. These findings illustrate that more coal rents from coal natural resource exploration would increase coal consumption, which in turn would increase the levels of CO_2 emissions and affect efforts for sustainable development. Likewise, increasing coal energy output for economic growth would increase levels of CO_2 emissions and negate sustainable development. Furthermore, the research findings suggest that imposing regulations on coal consumption would have no or minimal effects to reductions to CO_2 emissions levels in BRICS and this is similar to the PSC. Such findings would infer that instituting regulations for curbing pollution emissions and GHGs, is a good intention by Policymakers but may lead to coal exploration Firms to devise ways of reducing production costs to deliver rents based on world market prices. This assumption may increase the contributions of coal rents to GDP, but, would, on the other hand, frustrate efforts for curbing CO_2 emissions levels and sustainable development in both BRICS and PSC.

Additionally, the extension of investigations to PSC yielded results similar to those of BRICS economies. For instance, the empirical results elucidate the existence of a positive relationship between coal rents and CO_2 emissions for PSC. Also, the study results reveal that coal energy output has a positive relationship with CO_2 emissions in PSC. Both these findings exemplify that more coal rents from coal natural resource exploration would increase coal consumption, which in turn increase the level of CO_2 emissions and frustrate efforts to sustainable development. Similarly, the research findings indicate the existence of a positive relationship between GDP per Energy Use and CO_2 emissions in PSC. Hence, an increase in energy consumption for economic growth would increase levels of CO_2 emissions. Lastly, the empirical results reveal a negative relationship between renewable energy and nuclear energy output for the PSC. Consequently, an increase in the renewable and nuclear energy consumption would reduce CO_2 emissions levels and support efforts for green growth and sustainable development in PSC.

Therefore, these findings have implications for policymakers in each of the BRICS and PSC. Most importantly, by honoring and sustaining the commitments made by each country to the Paris Agreement (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 recent release of the SDG Index and Dashboard Report by Bertelsmann Stiftung-SDSN, the BRICS countries were globally ranked; 56, 62, 116, 71 and 108 (out of 157) respectively in their efforts towards sustainable development (SDG Index and Dashboard, 2017). 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, such marginal costs and extraction cost should continue to increase so that coal rents would be negative and thus deter the exploitation of coal for energy consumption. This will in turn result into high total marginal cost for the depletable (non-renewable) resources and the luck of incentives would discourage trade of coal on world commodity markets, which would lead to reduction of CO_2 emissions levels from coal energy output. According to the SDG Index and Dashboard, this will be one of the key instrument 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 for the BRICS and PSC. 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 conservation policies for de-carbonization. Such polies would encourage greater reliance on renewable (non-depletable) energy sources, such as solar, wind, among others, and nuclear energy output, which will lower CO_2 emissions and pave the way for attaining green growth and sustainable development.

Aside from coal rents, BRICS and PSC should re-consider the introducing and imposing of regulations in respect to CO_2 damage costs. Whereas most governments have either implemented or are considering the implementation of carbon tax and fines as a means of curbing CO_2 emissions, this action may have immediate effects on reducing pollution and uplifting environmental and social sustainability, but could in the long-run negatively affect economic growth. Since the research findings indicate a positive and statistically significant relationship between regulations (log coal rents and CO_2), and CO_2 emissions, it would be rather sensible to reduce the subsidies to fossil fuels and minimize coal production, or introduce market-based instruments like "Cap and Trade". Making fossil fuels like coal expensive would discourage their exploitation, and would further push governments to make investments in renewable or nuclear energy. Such initiatives highlight the significance of other non-economic elements in enabling the reduction of CO_2 emissions in order to pave the way for green growth and sustainable development.

Nonetheless, the research presents other policy implications and recommendations like the need to focus on low-carbonization. All countries need to explore the possibility of introducing or expanding their energy consumption-mix to include more renewable and nuclear energy. As suggested in recent research findings renewable and nuclear energy consumption have a positive effect on green growth and sustainable development, and have a negative and statistically significant relationship with CO_2 emissions.

Similarly, many researchers on the topic of clean energy from coal energy consumption have suggested the need to introduce technology, such as CCTs in the coal energy output systems for increasing efficiency and lowering pollution and GHGs. Therefore, strengthening research and development initiatives would play a crucial role in introduction and application of new technology in coal consumption. This would encourage deep de-carbonization in order to mitigate CO_2 emissions and ensure accomplishment of green growth and sustainable development. However, to succeed in all these policies, there is a need to increase government spending or attracting FDIs to ensure that the efforts of attaining green growth and sustainable development do not harm the all overarching governments' objective – Economic Growth (real GDP) together with sustainable energy access for all.

5.3 Limitations of the Study

Like all other research studies, this particular study is not without any limitations. Foremost, some of the key determinants of sustainable development, such as socio-economic well-being, climate change vulnerability, amongst other could not be included into the statistical models due to the absence of panel data and research time constraints for IV - GMM econometric regressions models. Also, it is important to acknowledge that some other changes have occurred in the BRICS and the PSC, as of end 2015. Nevertheless, the estimates may still show minor biases due to these changes as an effort has been made to control for these changes through the inclusion of country and time fixed effects.

In addition, the panel data-set for the study is aggregate annual data at the macro-national level from 1990 to 2015 and is used without alterations as obtained from the WD, 2017. It will be useful to consider micro-household level data to examine the disaggregated impact of coal rents, coal energy output, renewable energy output, nuclear energy output, GDP per energy use and regulations on a country-by-country level, rather than at the country-aggregate level. This could be a possible extension for future research to examine the relationships between coal rents and CO_2 emissions for any country, to provide policy recommendations on ways of attaining the SDGs.

Furthermore, the study was not able to apply the **IV approach** based on the **2SLS** or the Dynamic Panel estimators or the GMM. In order to confirm the robustness of the findings across distinct techniques, it would have been necessary to proceed to the 3rd econometric regression method using **Coal Energy Production (% of Energy Total)** as the **IV**. It is assumed that the coal energy production would be correlated with coal rents, but uncorrelated with any of the other contributors to CO_2 emissions, and also orthogonal to any other omitted characteristics - uncorrelated with the outcome of the interest through any channel other than their effects via the endogenous variables.

Therefore, pooled OLS and FE models have shortcomings centered on country-specific effects and do not consider for stationarity, dynamics and endogeneity, and thus this would require further study to apply the IV – GMM estimation model in order to eliminate any possibility of shortcomings in the study findings. The inconsistency of pooled OLS, FE and RE estimators is due to endogeneity, omitted variables, substantial bias, measurement errors and thus may yield misleading inference even when there is no correlation between individual effects and the regresors (Baltagi, Bresson & Pirotte, 2003; Murtazashvilia & Wooldridge, 2008; Hutcheson, 2011).

Despite the above concerns and limitations, the present study significantly and statistically enhances understanding of the relationship between coal rents and carbon dioxide (CO_2) emissions. Hence, the research findings are relevant for BRICS, PSC and other countries around the world to minimize (CO_2) emissions in order to strike a balance between environmental sustainability, social sustainability and economic development, which are the pillars of sustainable development.

5.4 Suggested Areas of Further Study

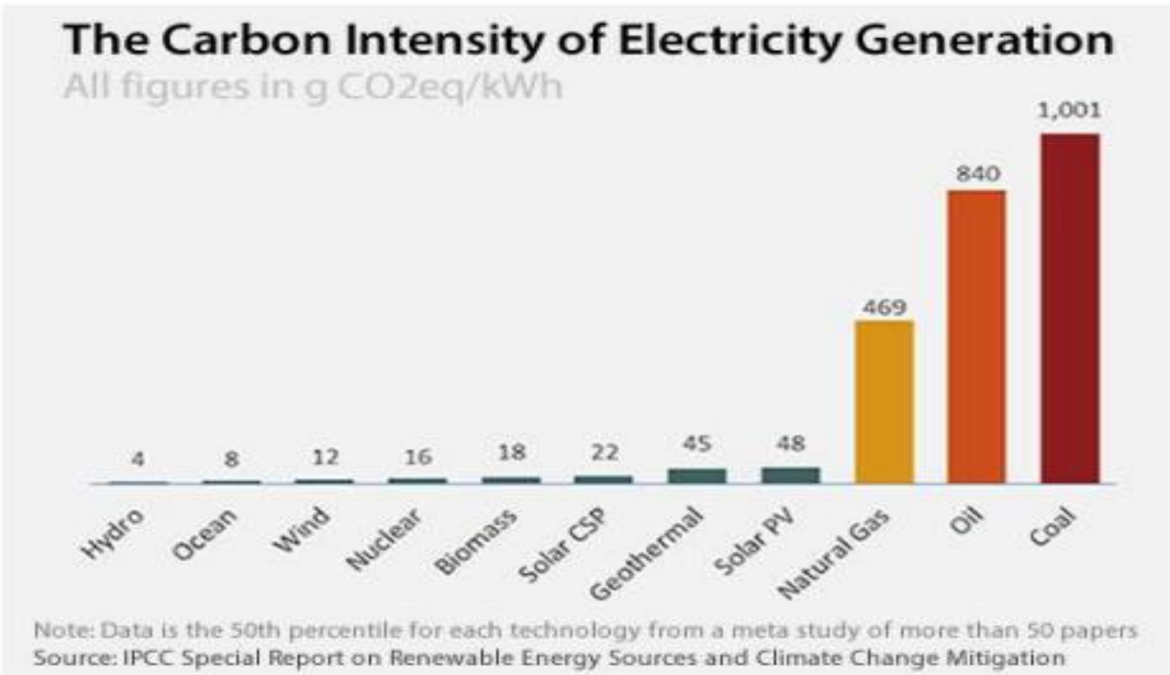
Subsequent to the limitations above, this study without exceptions presents suggested areas of further studies in an effort to get closer to the existing gaps in the literature related to energy consumption, economic growth and CO_2 emissions. Accordingly, it is recommended that considerable attempts should be made to examine the relationships between coal rents and CO_2 emissions at individual country-level. Such future study is expected to allow policymakers ascertain the relationship or effects of coal rents to CO_2 emissions for their country-specific and be able to design responsive policy directed to their countries on ways of attaining the SDGs, through the causal links between coal rents and CO_2 emissions. Therefore, future studies need to narrow down this sample further to one country to produce an even more specific result to make more country-specific policy recommendations. Additionally, it will be interesting to include other excluded determinants and contributors to CO_2 emissions in the study for examining the relationship between coal rents and CO_2 emissions.

Furthermore, this study's findings illustrate that there is a positive relationship between coal rents and CO_2 implying that benefits of coal consumption are lower than the externalities related to cost of energy and economic growth. Conversely, 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 be a setback to economic growth. This scenario creates policy implication for policymakers and might suggest that curbing coal rents or carbon dioxide (CO_2) emissions or imposing regulations on coal consumption might harm economic growth. Likewise, harming economic growth would frustrate efforts for accomplishment of the SDGs, green growth and sustainable development. In light of this point, further research would be necessary to further investigate the effects of coal rents to economic growth (real GDP) per se and provide robust analysis at the country-specific level for policymakers.

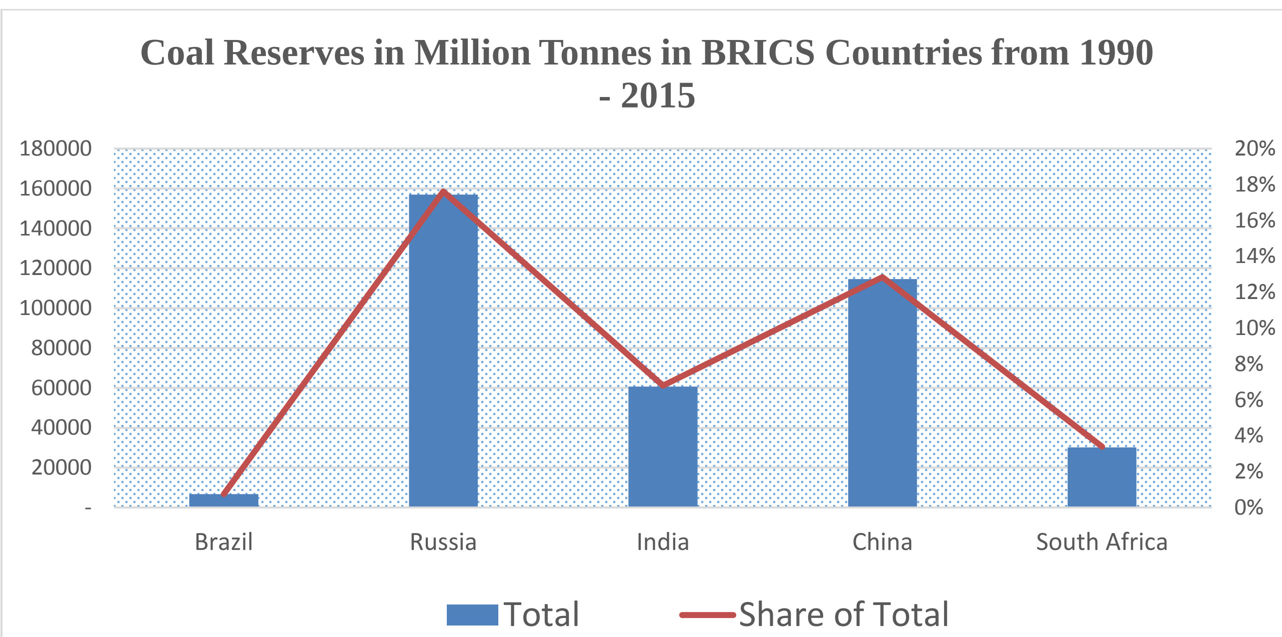
Finally, since this study is not able to apply the 3rd econometric technique of IV and GMM, some scholars may have doubts about the robustness, endogeneity and measurement errors in the estimates of the study. To eliminate any future suspicions and fully accept the study estimates in the literature, it will be interesting for future research to examine the relationship between coal rents and carbon dioxide (CO_2) utilizing the IV-GMM estimation techniques after the pooled OLS and FE econometric estimation regression models. This might be important to analyze or compare the estimations of the future research, using the same data-set sample with the estimations of this study for robustness and bias elimination. Understanding the causal links between coal rents and CO_2, using appropriate estimation techniques might provide insights into respective governments regarding energy consumption and economic growth and coming up with alternative energy sources to curb environmental and social degradation without harming economic growth for sustainable development.

6 *APPENDICES*

Appendix 1: Carbon Dioxide (CO_2) Emissions from Energy Consumption

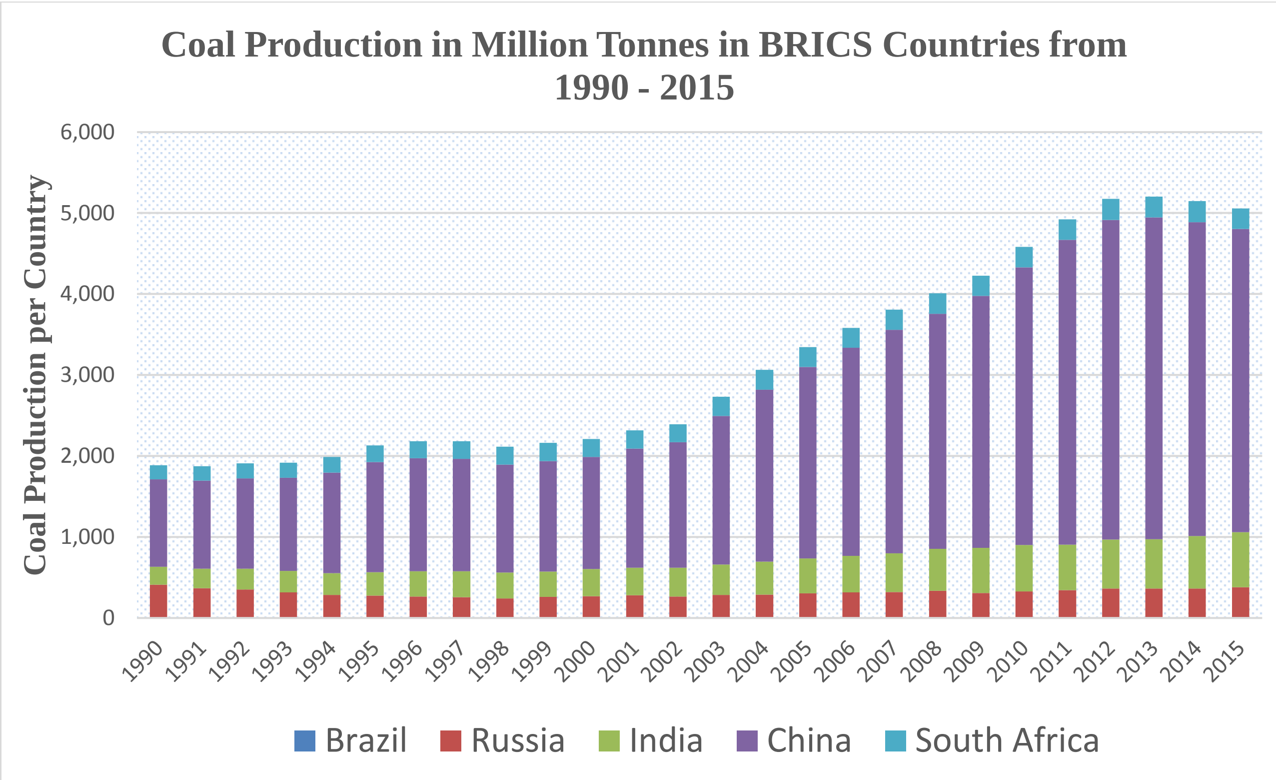


Appendix 2 – Graph representing Coal Reserves in BRICS Countries



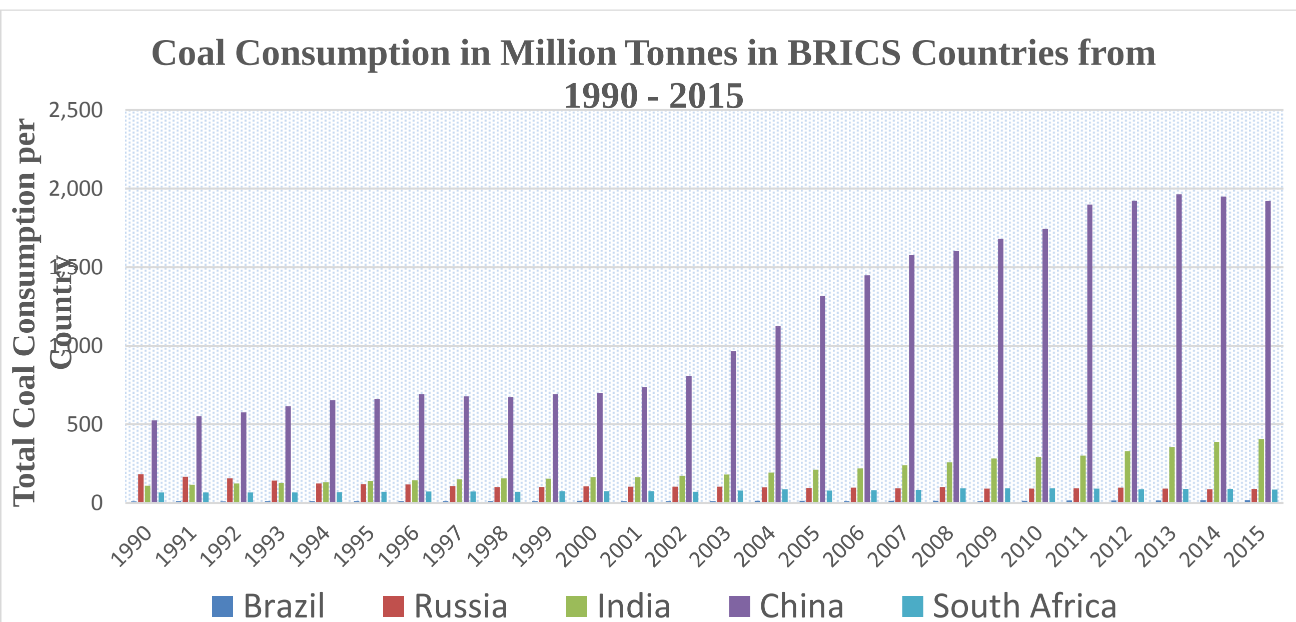
Source: Author's Compilation

Appendix 3: Graph representing Coal Production in BRICS Countries



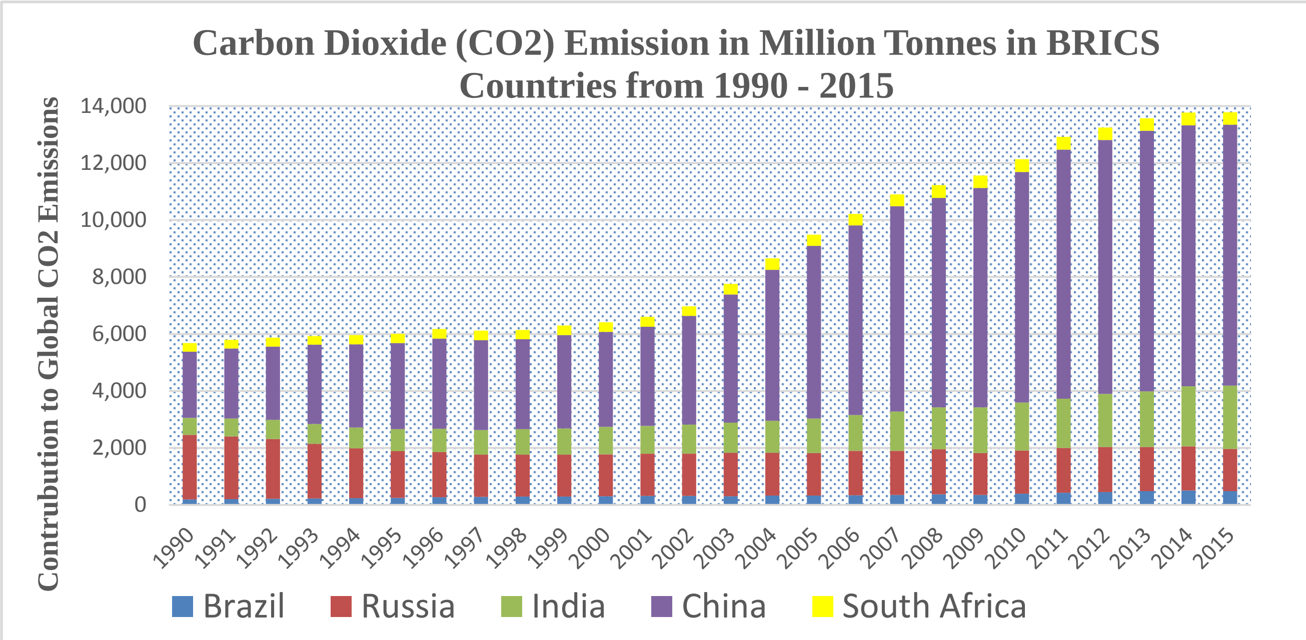
Source: Author's Compilation

Appendix 4: Graph representing Coal Consumption in BRICS Countries



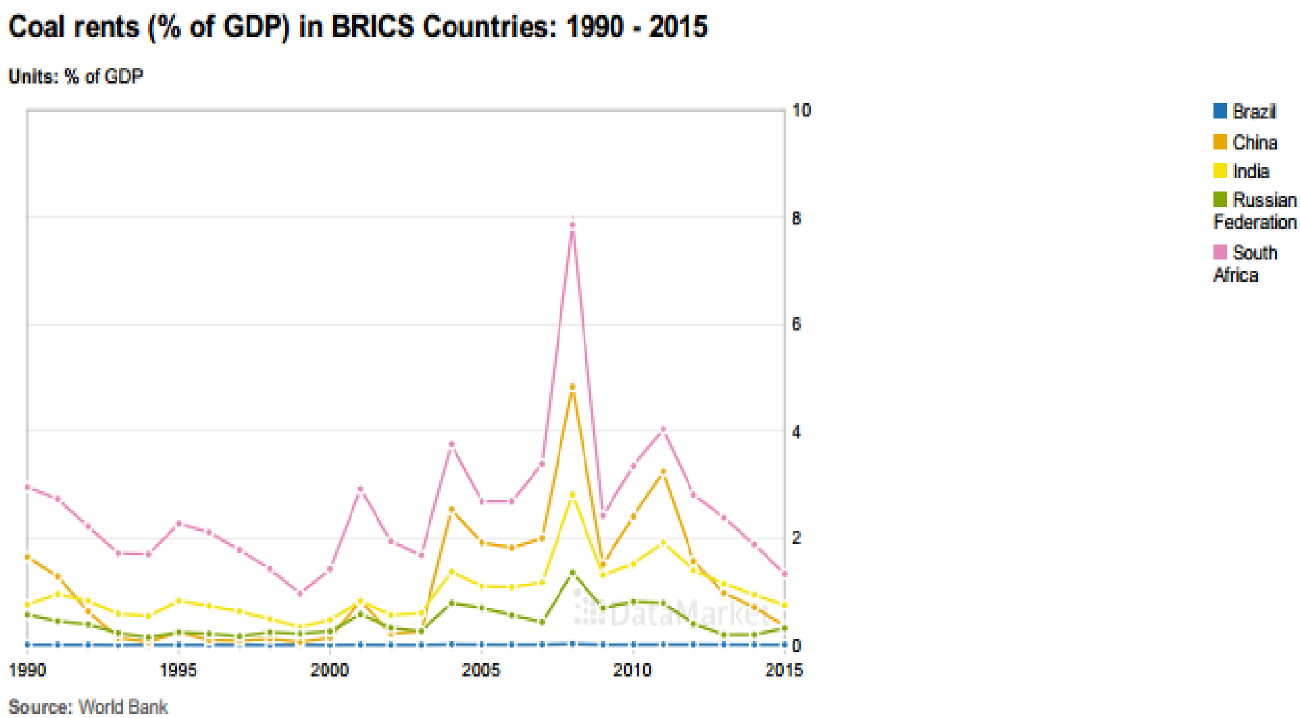
Source: Author's Compilation

Appendix 5: Graph representing Carbon Dioxide (CO_2) Emissions in BRICS Countries

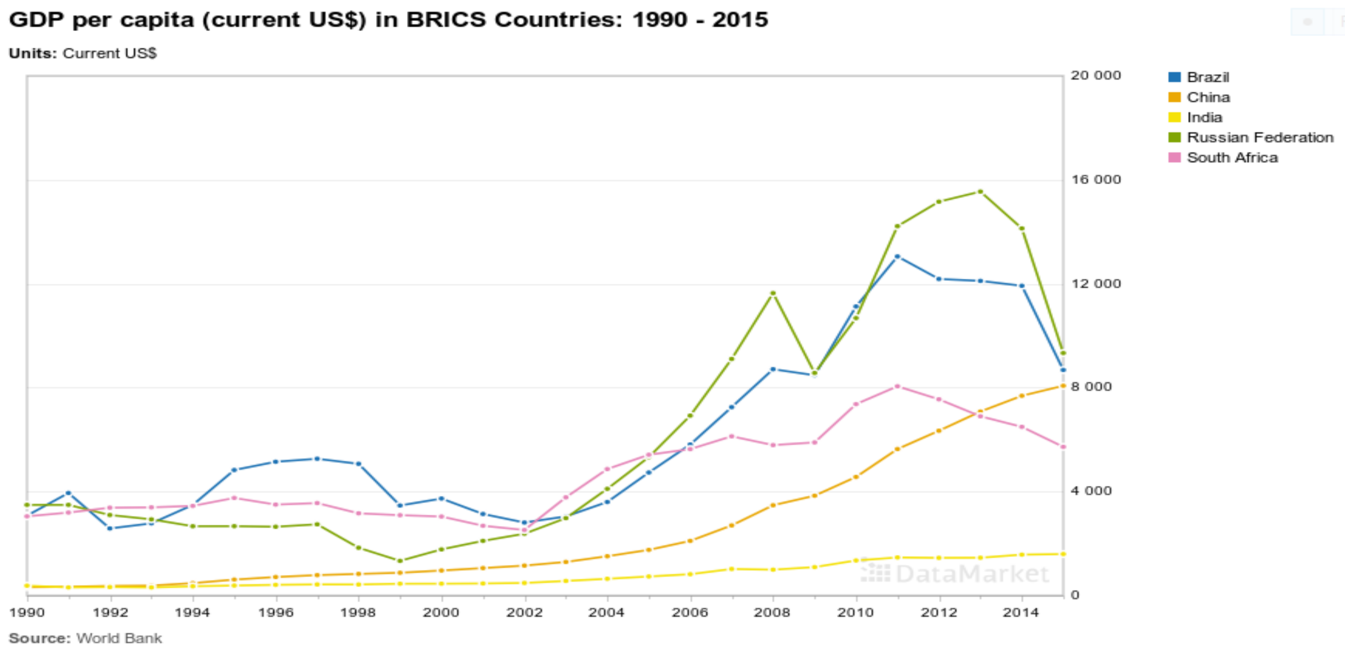


Source: Author's Compilation

Appendix 6: Coal Rents (% of GDP) in BRICS Countries: 1990 - 2015



Appendix 7: GDP per capita (current US$) in BRICS Countries: 1990 - 2015

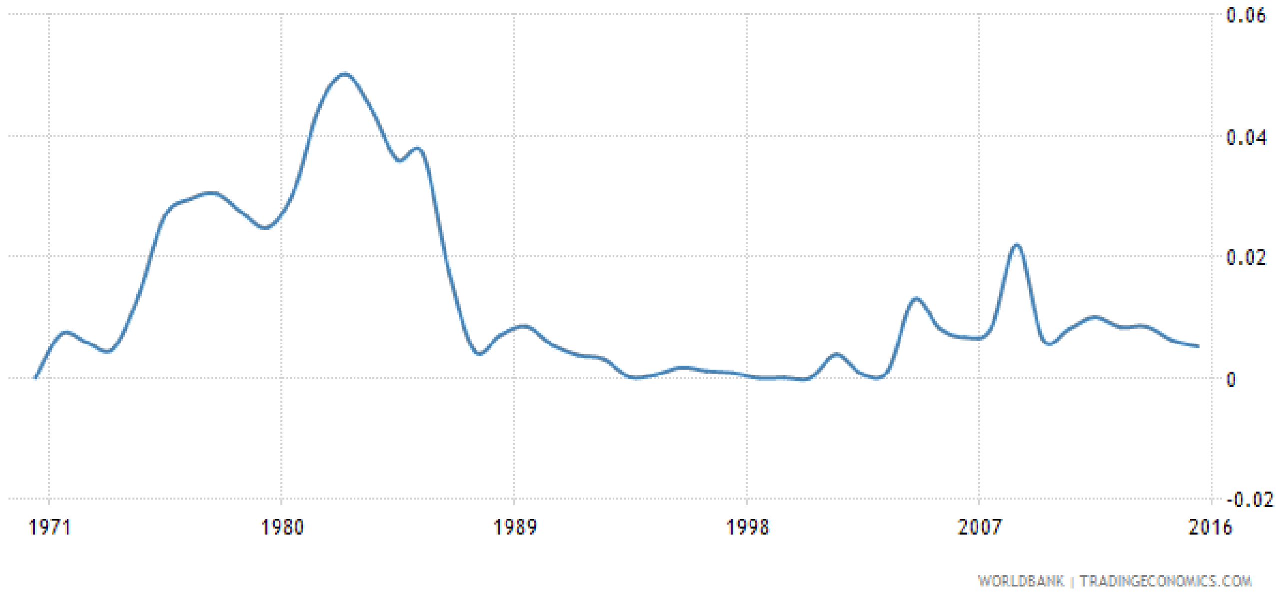


Appendix 8: Countries Earning the Most in Coal Rents relative to GDP, 2015

Rank	Country	% of GDP Sourced From Coal Rents
1	South Africa	1.9%
2	Kazakhstan	1.5%
3	Ukraine	1.2%
4	Mozambique	1.1%
5	Indonesia	1.0%
6	Zimbabwe	0.8%
7	China	0.7%
8	India	0.7%
9	Russia	0.6%
10	Estonia	0.5%

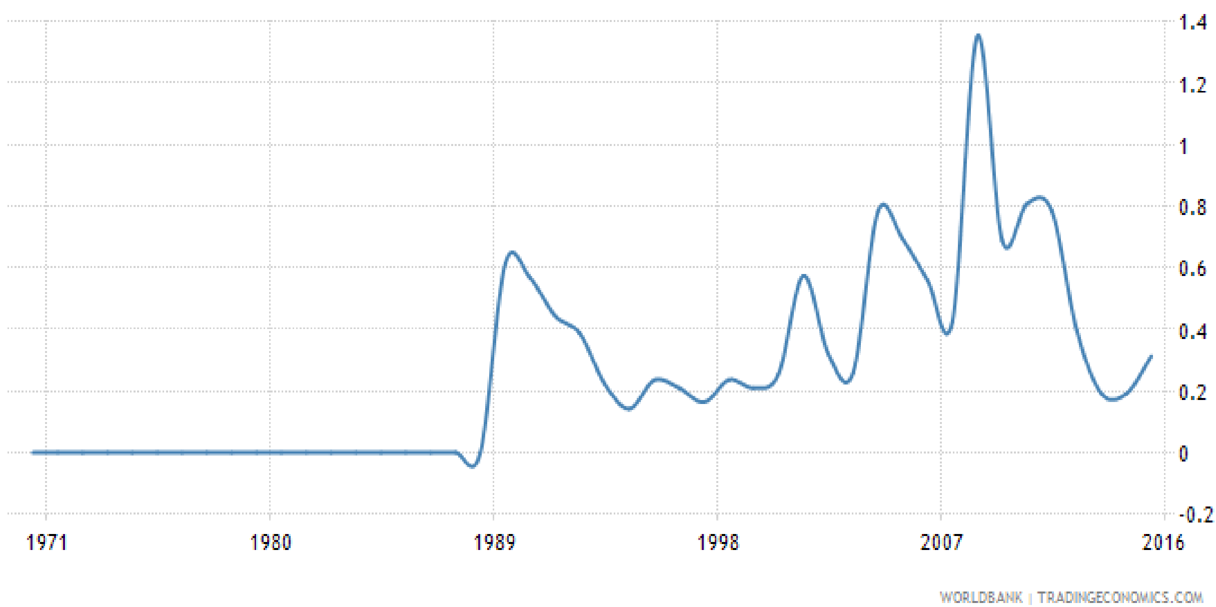
Source: World Bank: www.tradeeconomics.com

Appendix 9: Brazil – Coal Rents (% of GDP) 1970 - 2016



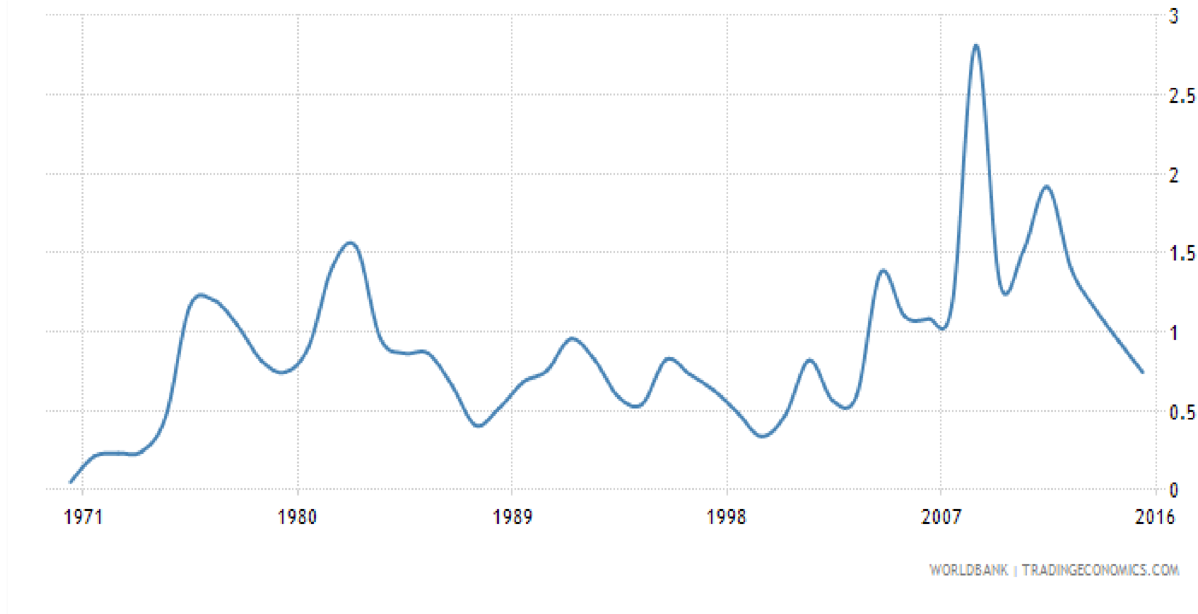
Source: World Bank: www.tradeeconomics.com

Appendix 10: Russia – Coal Rents (% of GDP) 1970 - 2015



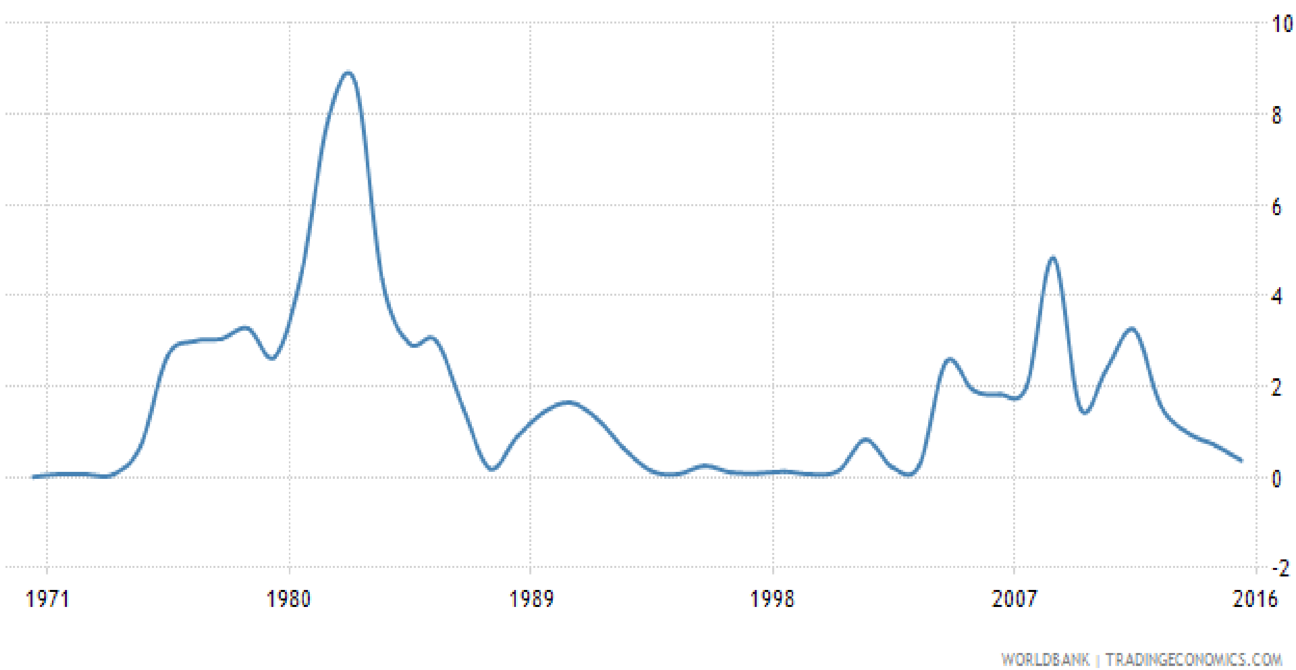
Source: World Bank: www.tradeeconomics.com

Appendix 11: India – Coal Rents (% of GDP) 1970 - 2015



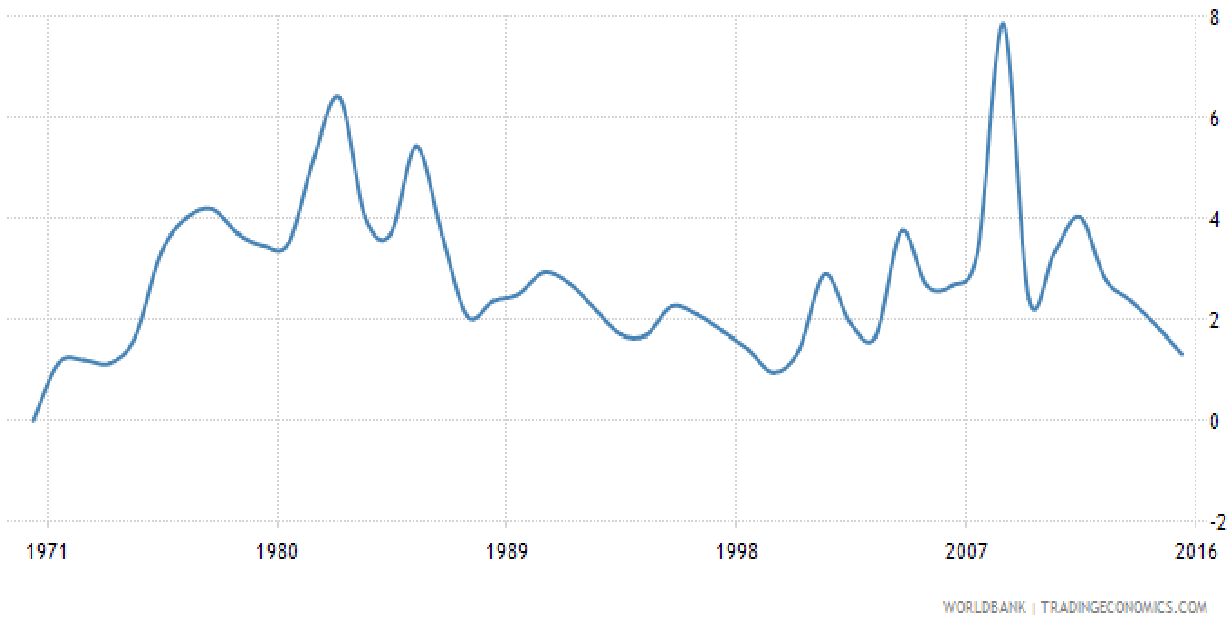
Source: World Bank: www.tradeeconomics.com

Appendix 12: China – Coal Rents (% of GDP) 1970 - 2015



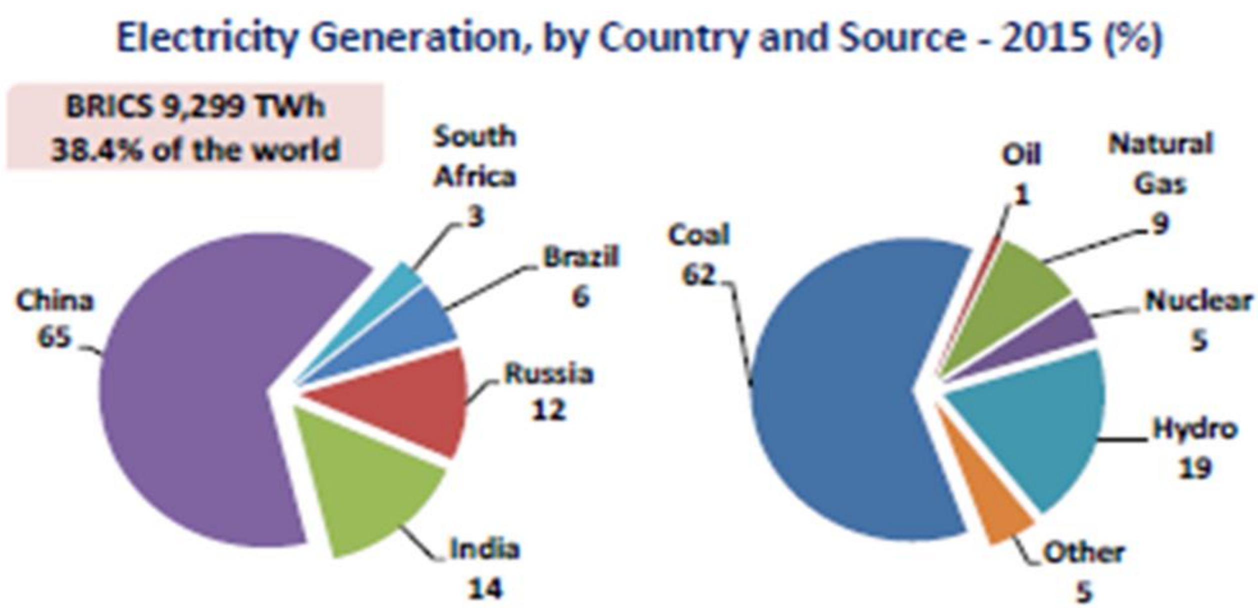
Source: World Bank: www.tradeeconomics.com

Appendix 13: South Africa – Coal Rents (% of GDP) 1970 - 2015



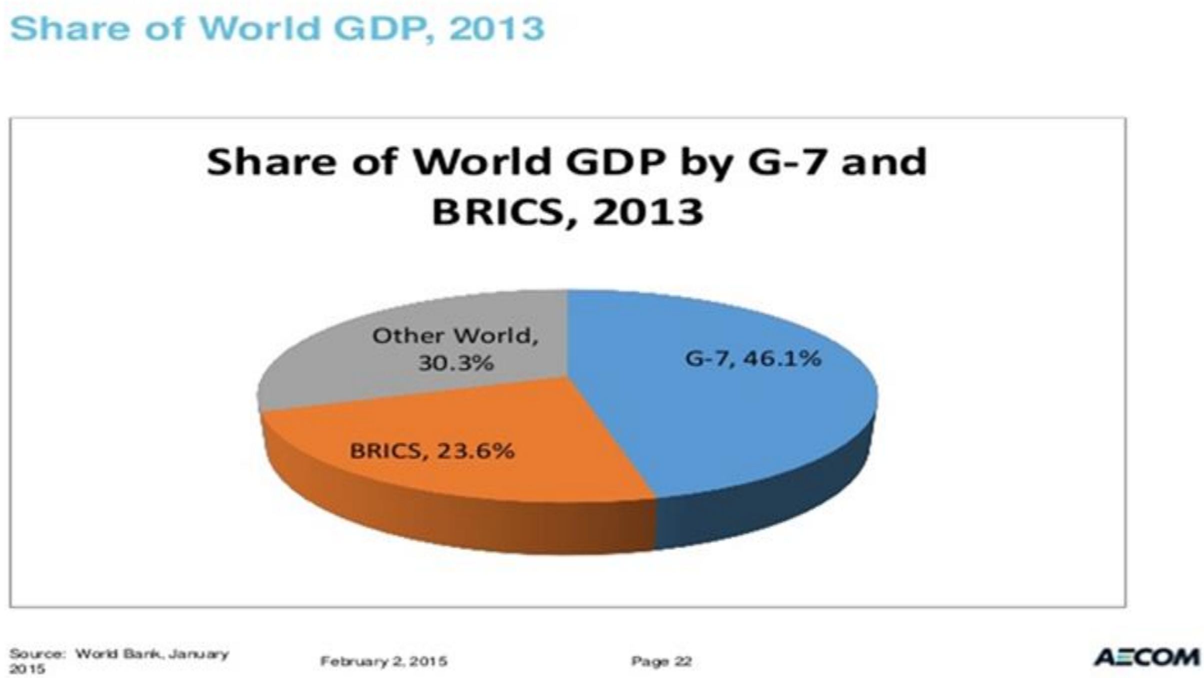
Source: World Bank: www.tradeeconomics.com

Appendix 14: Energy Output by Sources in BRICS Economies, 2015



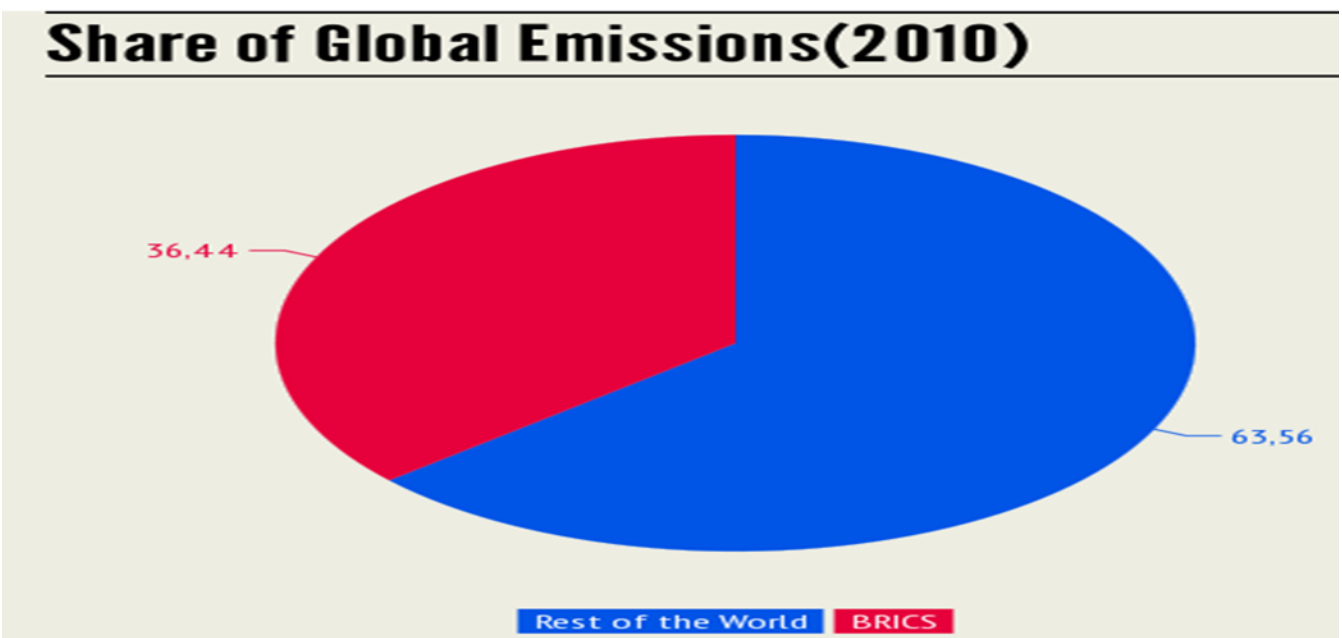
Source: Statistics of Russia, 2015

Appendix 15: GDP of BRICS Economies as a Percentage of World GDP, 2013



Source: World Bank, 2015

Appendix 16: BRICS Economies Share of Global CO_2 Emissions, 2010



Source: Rosstat - Statistics of Russia, 2015

Appendix 17: List of the Panel of Selected Countries for the Study

Country	*Country*	*Country*	*Country*
1. Albania	16. France	31. Mexico	46. Spain
2. Argentina	17. Georgia	32. Mongolia	47. Swaziland
3. Australia	18. Germany	33. Morocco	48. Sweden
4. Austria	19. Greece	34. Mozambique	49. Tajikistan
5. Belgium	20. Hungary	35. New Zealand	50. Tanzania
6. Bosnia and Herzegovina	21. Indonesia	36. Nigeria	51. Thailand
7. Botswana	22. Iran, Islamic Rep.	37. Norway	52. Turkey
8. Bulgaria	23. Ireland	38. Pakistan	53. Ukraine
9. Canada	24. Italy	39. Peru	54. United Kingdom
10. Chile	25. Japan	40. Philippines	55. United States
11. Colombia	26. Kazakhstan	41. Poland	56. Uzbekistan
12. Croatia	27. Korea, Rep.	42. Mexico	57. Venezuela, RB
13. Czech Republic	28. Kyrgyz Republic	43. Mongolia	58. Vietnam
14. Denmark	29. Lao PDR	44. Morocco	59. Zambia
15. Dominican Republic	30. Malaysia	45. Mozambique	60. Zimbabwe

Source: Author's Compilation

6.1 Additional Literature Review on the Study

This study had an extensive literature review in addition to what has been provided and summarized in Chapter 2. This includes literature relating to energy consumption, CO_2 emissions and externalities to environment and social degradation in respect to the BRICS economies, application of CCTs for clean energy and key factors for CCTs success, including policy recommendations from previous studies. In order to enrich the study and provide the necessary capacity to closing the literature gap, the above additional literature has been provided as appendix.

6.1.1 Energy Consumption and CO_2 Emissions for Social Sustainability in BRICS

In emphasizing how energy or coal consumption and economic growth have contributed to Carbon Dioxide (CO_2) emissions with specific emphasis to the 5 BRICS Countries, many studies have examined the environmental and social aspects of energy consumption by exploring the causality between economic growth and CO_2 emissions in each of the nations. Respectively, Pao & Tsai (2010) using co-integration and Granger causality for a panel of 4 BRIC countries (excluding South Africa) examined causality relationships between energy consumption, pollutant emissions and GDP over the period from 1971 to 2005, except for Russia (1990 to 2005). The research findings illustrated the existence of causal links between energy consumption, pollutant emissions and real GDP for BRIC panel of countries. It concluded that with a rise in energy consumption, CO_2 levels, especially from fossil fuels rose.

Wang, Zhou, Zhou & Wang (2011) using co-integration and Panel VECM explored the relationship between economic growth, CO_2 emissions and energy consumption in 28 Provinces in China for data of the period between 1995 and 2007. Their research findings indicated causality between energy consumption and CO_2 emissions, which implies that economic growth and energy consumption are major causes of CO_2 emissions in China. In another research by Bloch, Rafiq & Salim (2012), they studied the causality between income and coal consumption and with demand- and supply-side data using co-integration and Panel Vector Error Correction on data from 1977 to 2008 (Supply) and 1965 to 2008 (Demand) in China. The study findings 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).

Similarly, Farhani, Shahbaz & Ozturk (2014) using structural break unit root test, co-integration and VECM explored the relationship between industrial production, coal consumption and CO_2 emissions in China and India on data between 1971 and 2011. The study concluded that coal consumption and industrial production Granger-cause CO_2 emission in India, while the same was true for China with feedback effect between CO_2 emissions and coal consumption. In addition in South Africa, Odhiambo (2012) using the ARDL-Bounds testing approach examined causality relationship between economic growth and carbon dioxide (CO_2) emissions with time data series for the period from 1970 to 2007. The findings of the study showed causal uni-directional relationship flowing from economic growth to CO_2 emissions, thus energy consumption causal-cause CO_2 emissions and economic growth in South Africa. Likewise, Lin & Wesseh (2014) re-assessed causality inter-dependence between economic growth and energy consumption in South Africa with time series data for the period from 1971 to 2010 using the Non-parametric bootstrap method. The research findings concluded that there exists causal uni-directional link flowing from energy consumption to economic growth and from employment to economic growth.

Shahbaz, Tiwari, & Nasir (2013) studied the relationship between trade openness, financial development, economic growth, CO_2 emissions and coal consumption using ARDL bounds testing and co-integration on time-series data from 1965 to 2008 in South Africa. The findings showed that there exists positive relationship among all variables; with economic growth rise resulting into CO_2 emissions increase, while financial development reduces CO_2 emissions and coal consumption leads to CO_2 emissions. In the case of Brazil, De Freitas & Kaneko (2011) evaluated the determinants of CO_2 emissions changes from energy consumption using the Decomposition approach Model to time series data from 1970 to 2009. The study showed that economic growth and demographic pressure are the leading factors causing the escalation of CO_2 emissions.

Furthermore, Cowan, Chang, Inglesi-Lotz, & Gupta (2014) using a Panel Causality Analysis and Panel Bootstrap Method explored the causality relationship between economic growth, electricity consumption and CO_2 emissions in the 5 BRICS panel of countries with time-series data from 1990 to 2010. The study findings illustrated the existence of causal relationships between all the variables, but with different Ganger-direction among the different BRICS countries. For China and India, Govindaraju & Tang (2013) examined the links between CO_2 emissions, coal consumption and economic growth using the co-integration technique and granger causality test on time series data from 1965 to 2009. The study findings showed the existence of co-integration in China, but not in India, while both India and China showed a causal uni-directional relationship running from economic growth to CO_2 emissions.

Pao, Yu & Yang (2011) deployed co-integration technique and Ganger causality test to explore the relationships between CO_2 emissions, energy consumption, and real GDP on time series data from 1990 to 2007 in Russia. Their research findings showed the existence of positive relationship between CO_2 emissions, energy use and real output (GDP). Lastly, Pao & Tsai (2011) using the co-integration technique investigated the relationship of Foreign Direct Investment (FDI) and economic growth on environmental degradation in 4 BRIC countries on panel data from 1980 to 2007, except for Russia (1992 to 2007). The results of the study concluded that a causal bi-directional relationship between CO_2 emissions and FDI exists, and between output GDP and CO_2 emissions, whereas a causal uni-directional relationship exists between energy consumption and CO_2 emissions.

6.1.2 Clean Coal Technology in Reducing Environmental and Social Degradation

Clean Coal Technology (CCTs) is a set of instruments or applications through which dirty energy sources like Coal are processed to generate clean energy, and lowering GHGs emissions that affect the environment and social wellbeing. CCTs mainly refer to advanced power generation technologies of high proficiency ignition that includes; coal-to-chemicals (gas or liquids), Integrated Gasification Combined Cycle (IGCC), Pulverised Coal Technologies (PCTs), Carbon Capture and Storage Technologies (CCSTs) and Fluidized Bed Combustion (CFBC) (Na, et al, 2014). These CCTs are a collection of technologies developed to mitigate the effects to the environment and social well-being from burning coal for energy generation and thus deliver clean energy for green growth and sustainable development. Li & Li (2011), in their study on coal consumption in India and China, recommended that the development of CCTs, which are cleaner and more efficient systems to reduce carbon dioxide (CO_2) emissions for achieving the desired sustainable development.

Although coal continues to play a key part in the new installation of power generation plants in many countries, this energy generation causes inevitable environment and social problems. Therefore, Clean Coal technologies (CCTs) are critical in reducing or minimizing CO_2 emissions in the energy sector (Zhao & Chen, 2015). It has been also noted that most developing countries are exploring possibilities of deploying CCT systems to generate clean energy from coal-fired power plants (Phoumin, 2015). Even though, energy power plants using coal are considered high pollutants, new coal-fired plants are set to be established in ten (10) countries - Uzbekistan, Cambodia, Guatemala, Namibia, Oman, Senegal Laos, Morocco, Sri Lanka, and Dominican Republic (Yang & Yiyum, 2012). Ujam & Diyoke (2013) in their research on economic feasibility of coal based power generation plants in Nigeria, asserted that CCTs are technically proven, cost-effective and dependent on a cheaply available energy resource to control the impact of CO_2 emissions and that greenhouse gas impacts are controlled during the process of generation of clean energy from coal consumption in coal-fired power stations.

6.1.3 Key Factors in the Successful Implementation of Clean coal technology (CCTs)

Globally, coal endures as the dominant source of energy for both developed and developing economies, and the largest single fossil fuel used for electricity generation in respect to non-renewable energy-mix. In order to address energy demand for green growth and sustainable development agenda, developing countries will most likely carry-on relying on low-cost coal-fired power plants. Since using coal energy is the main source of global warming and GHGs, researchers have recommended the implementation of CCTs to minimize the effects of climate change and global warming. Therefore, it is critical to identify key factors for a successful implementation of CCTs in generation of clean energy. The challenges of climate change and international pressure increase the urgency of implementing CCTs in burning coal for all coal-dependent countries, including the BRICS economies. Accordingly, a number of studies have emphasized the role of Government – Private Partnerships, Capital (Costs), Citizen Participation, Research and Development and Legal and Administration issues as success factors of CCTs application for the delivery of clean energy. Bezdek & Wendling (2012) indicated that CCTs in the USA were deployed under a public-private partnership (PPP), with the share of federal government funds limited to a maximum of one-half of the funding for each project. Another study by Ujam & Diyoke (2013) concluded that an enormous amount of capital investment will be required to reach the development goals for new CCTs for power generation from coal in Nigeria.

In addition, Tang, et al. (2015) examined the deployment challenges faced by China towards CCTs applications in coal-fired power plants in generation of clean energy for green growth and sustainable development. Their findings indicated that successful implementation of CCTs in China required high-legal obligations and compulsory regulations for greenhouse gasses (GHGs) related to coal use, to enforce the nonexistence of laws for clean coal use. As regards to citizen involvement and environmental factors, Van Den Berge (2009) asserted that the public does not have a good understanding and is not well informed about CCTs issues. On the other hand, research by Lua et al. (2008) investigated obstacles to implementing CCTs in China and indicated the lack of institutional and managerial systems for coordination of CCTs developments. However, Musango & Brent (2011) in their research to review the energy technology valuation tactics and tools in the Southern African Region stressed the need for policy direction related to developing of new technology to support energy generation, especially for fossil fuels power generation technologies.

6.1.4 Previous Policy Recommendations on Energy Consumption and CO_2 Emissions

Following numerous studies on the relationship between economic growth, energy (coal) consumption and CO_2 emissions, scholars have suggested key policy recommendations for improvement energy system efficiency, thereby assist nations in accomplishing green growth and sustainable development agenda. In the key policy recommendations, the need to transform dirty energy into clean energy by the application of clean coal technology in the energy generation systems to prove efficiency, and the move to renewable energy and greener energy sources features prominently. For example, Pao & Tsai (2010) proposed to the 4 BRIC countries the need to increase investment in energy and energy system efficiency, and thus step-up energy conservation policies that would reduce energy wastage. Wang, Zhou, Zhou & Wang (2011) suggested to change the coal energy consumption dominated structure to clean energy and renewable energy sources, such as nuclear and Gas for the 28 provinces in China. Similarly, Bloch, Rafiq & Salim (2012) recommended the replacement of coal subsidization policy with a new policy of subsidizing greener energy sources to reduce CO_2 emissions in China. Farhani, Shahbaz & Ozturk (2014) recommended that both China and India should improve coal utilization efficiency, apply clean coal technology and increase usage of renewable energy sources to reduce coal consumption.

In addition, Odhiambo (2012) recommended that South Africa needed to explore appropriate forms of renewable energy coupled with energy conservation policies, in order to reduce CO_2 emissions, without affecting GDP growth levels. Shahbaz, Tiwari, & Nasir (2013) underscored the need for long-term value of CO_2 emissions, and recommended the design of policy framework that encourages research and development in new technology to minimize CO_2 in South Africa. While Lin & Wesseh (2014) proposed developing more balanced energy-mix composed of higher share of renewable sources of energy to reduce South Africa's CO_2 emissions. For Brazil, De Freitas & Kaneko (2011) recommended the diversification of energy-mix towards lower CO_2 emissions and clean energy matrix.

Likewise, Govindaraju & Tang suggested instituting coal utilization policy to increase efficiency rather than negatively impact GDP as coal conservation policy could reduce CO_2 emissions with feedback for China and India. While in Russia, Pao & Yang (2011) recommended considering environmental concerns in macro-economic policy as part of reducing CO_2 emissions, without negatively impacting levels of economic growth. For the 4 BRIC countries, Pao & Tsai (2011) proposed the increase in energy supply investment and energy system efficiency, and adoption of new technologies to minimize CO_2 emissions. Similarly, Cowan, Chang, Inglesi-Lotz, & Gupta (2014) suggested that reducing CO_2 emissions levels could be achieved with countries making improvements in the techniques of energy production, and new technology, while increasing economic productivity for 5 BRICS Countries.

6.2 Green Growth and Sustainable Development in BRICS Countries

The need to increase economic growth for any country is most likely to lead to increase in energy consumption, urbanization, and industrialization. This in turn causes environmental problems like depletion of natural resources, increased pollution, which are associated with global warming and climate change. In order to ensure a balanced growth phenomenon whereby economic development, environmental sustainability and social sustainability are in sync, countries may have to re-examine their policies related to green growth or green economy, thereby re-direct their efforts towards the top-most goal of sustainable development. This would require the vital role of energy and environmental resources management to preserve the future economic growth, while reducing the levels of GHG emissions.

Despite the overarching requirement to develop a path to green growth and sustainable development, policymakers in the BRICS countries seem to possess contrary views on the concept of green growth vis-à-vis acceleration of economic growth and consideration of environmental and social degradation. Considering that BRICS countries are both coal dependent and their economic growth demands the high-energy intensive activities, green growth may negatively affect economic growth. For instance, Brazilian policymakers are of the view that green growth concept can be suitable for developed economies as well as developing economies do not have additional resources to develop environmentally friendly technologies for efficient energy consumption. On the contrary, Russia policymakers seem to support the concept of a green growth for long-term sustainable development of their economy, and have developed a network of environmental institutions and legislative frameworks in cooperation with international organizations (Maryam, Mittal & Sharma, 2017).

Indian policymakers have openly embraced green growth and come up with elaborate policies to make their energy mix greener. Although China's rapid economic growth as the highest emitter in the world has been achieved with huge costs to environmental and social degradation, policymakers have now outlined strategy towards green growth and thus moving towards curbing the high levels of CO_2 emissions. South Africa, as Africa is G-20 representative views the concept of green growth in high esteem and a viable path towards sustainable development. The country has made vital investments in green energy sectors and developed energy and environmental policies to encourage green growth. Through its National Development Plan (NDP), which was released in 2011, policymakers have made commitments on transition to lo-carbon technologies, reduce coal consumption and increase renewable energy consumption (Maryam, Mittal & Sharma, 2017).

The concepts of green growth, sustainable development and climate change have put the question of how energy consumption and economic growth sustainability can be achieved in a manner that the environment and social well-being are not compromised, and thus create a viable path to sustainable development. Although the BRICS countries have instituted CO_2 emission control policies, such as Carbon Tax, abolition of fossil fuel subsidies, amongst others, more efforts needs to made to reach green growth and sustainable development targets in the medium to long term. BRICS countries and all other countries that embrace the concept of green growth must actively frame and implement 'green' policies to transform economic expansion and to develop sustainably.

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