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Modeling cointegration and causality between renewable energy, non-renewable energy consumption and economic growth nexus in BRICS countries

Modelando Cointegración y Causalidad entre Consumo de Energía Renovable, Consumo de Energía no Renovable y Crecimiento Económico en Países BRICS

Tesis para optar al grado de Magíster en Economía
de Recursos Naturales y del Medio Ambiente

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Dedication

This thesis is first dedicated to God who has been my Father and provider, my family mother Faith Nyaniswa, and my sisters Bongeka and Sisipho who always desire to see their brother finishing the studies, grandfather who from the begging of my tertiary level studies always have a smile on his face with words saying continue to make me proud my grandson, to my cousin Sihle who is always close in my heart, my nephews Anam and Asavela.

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I thank God for giving me this opportunity to study at this level. the If God was not on my side I could not have finished, as it is stated in the book of James 1:16. “Every good and every perfect gift is from above and cometh down from the Father of Lights, with whom the is no variableness, neither shadow of turning” to God I give all the Glory.

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Contents

INDEX OF TABLES

INDEX OF FIGURES

“Modeling panel cointegration and causality between renewable energy, non-renewable energy consumption and economic growth nexus in BRICS countries”

ABSTRACT

In this paper, we investigate the causality relationship between economic growth and renewable energy consumption (REC), non-renewable energy consumption (NREC) for BRICS countries over the period of 1990-2014. We apply panel unit root tests, panel cointegration tests, and panel Granger-causality tests. Our empirical results confirm that all panel unit roots tests are stationary after first difference, and also denotes the long-run relationship through the application of Pedroni and Kao panel cointegration tests among the variables and Granger-causality results supports feedback hypothesis which means a bidirectional relationship between REC and GDP, and TFEC and GDP in both the short-run and long-run, while in contrasts NREC-GDP supports growth hypothesis in long-run and supports neutral hypothesis is the short-run.

Keywords: Panel Cointegration, Panel VECM, Economic Growth, Renewable and Non-renewable Energy Consumption

“Modelando Cointegración y Causalidad entre Consumo de Energía Renovable, Consumo de Energía no Renovable y Crecimiento Económico en Países BRICS”

Resumen

En este artículo, investigamos la relación de causalidad entre el crecimiento económico y el consumo de energía renovable (REC), el consumo de energía no renovable (NREC) para los países BRICS durante el período 1990-2014. Aplicamos pruebas de raíz de unidad de panel, pruebas de cointegración de panel y pruebas de panel de causalidad de Granger. Nuestros resultados empíricos confirman que todas las pruebas de raíz de unidad de panel son estacionarias después de la primera diferencia y también denota la relación a largo plazo mediante la aplicación de pruebas de cointegración de panel de Pedroni y Kao entre las variables y los resultados de causalidad de Granger respaldan hipótesis de retroalimentación que significa una relación bidireccional entre REC y GDP, y TFEC y GDP tanto a corto como a largo plazo, mientras que en contrastes NREC-GDP apoya la hipótesis de crecimiento en el largo plazo y apoya la hipótesis neutral en el corto plazo.

Palabras clave: cointegración de panel, panel VECM, crecimiento económico, consumo de energía renovable y no renovable

1. Introduction

The interrogation of whether energy conservation policies affect or not the economic growth or rather energy consumption could have unintended consequences for economic growth attract much attention for investigations thus modeling panel cointegration and causality between non-renewable energy consumption, renewable energy consumption, and economic growth has active in the area of research both in economics and econometrics perspectives (see, for example Apergis & Payne (2010); Baltagi & Kao (2000); Breitung & Lechner (1998); Cowan, Chang, Inglesi-lotz, & Gupta (2014); Inglesi-Lotz (2015); Ito (2017); Pedroni (1999)) and more than 90% of these studies have applied neo-classical aggregate production, model.

Since the signing of both Kyoto protocol and Paris agreement, a drastic shift within the energy sector has been evident in both developed and developing economies around the world, through the implementation of effective policies that resulted in a shift from non-renewable energy to renewable energy production, investment, and consumption. Subsequently from 2010 BRICS group having been conducting summit to tackle their way forward with trade policies and implementation, promoting finance, energy, and investment for economic infrastructure for all sectors.

The initial concept BRICs was first coined in 2001 by the former chairman of Goldman Sachs Asset Management O'Neill, in his paper titled "Building Better Global Economic BRICs,", however, now BRICS is the association consisting of five emerging economies/countries namely Brazil, Russia, India, China, and South Africa from four continents. In 2013 BRICS held their fifth annual summit which was hosted by South Africa, wherein the members agreed to establish the development bank and expanded their cooperation up to the inclusion of energy sector.

With BRICS countries being energy intensive it is of great interest to pinpoint what direction must they follow, thus the rationality of this study is to answer the following questions about energy and growth policies: Will they implement expansive energy policies that will mean REC or NREC each causes economic growth? Or conservative energy policies must be implemented without any incompatible effect on economic growth? Does renewable energy consumption lead the way for the non-renewable energy consumption in both the short and long run? Is it optimal for the BRICS development bank to loan renewable projects in the short-run or long-run? What difference do we get estimating the total final energy consumption which is the sum of REC and NREC?

To answer these questions we revisit the model of neo-classical aggregate production through estimating optimal panel Cointegration tests Pedroni (1999) and Kao (1999) techniques after carefully testing for the stationary and relevance of the variables and causality relationship (both short-run and long-run) between the variables, that is to say exploring the direction of the causality through the application of Granger causality tests and VECM respectively. Estimating renewable, non-renewable, and total final energy consumption separately which is also optimal to avoid multicollinearity Cerdeira Bento & Moutinho (2016). The detailed approach is properly outlined and explained in the methodology section 6 of the study including unit root tests for variables stationarity and Fully Modified Ordinary Least Squares FMOLS and Dynamic OLS for the long-run relationship.

There are countable panel data studies about growth-energy nexus in BRICS countries and to our understanding, these include work by Cowan et al. (2014 Liu, Zhang, & Bae (2017 Sebri & Ben-Salha (2014), and all these studies have tackled this nexus by applying different models, data, and variables. Notwithstanding the fact that previous studies have extensively investigated the energy-growth nexus, however, no study within BRICS countries have considered modeling panel cointegration and panel causality from both renewable and non-renewable energy consumption and their relationship with economic growth per capita,

The contribution of this study is to extend the empirical work or empirical literature in the panel data cointegration and causality analysis for the energy-growth nexus especial in the non-random country selection like BRICS countries as the association still has less than 10 years. Secondly the choice of BRICS countries contain substantial value in energy consumption as Russia, India, and China are within the top four energy consumption countries in the world Shahbaz, Zakaria, Shahzad, & Mahalik (2018), wherein South Africa is the biggest energy consumer in Africa and Brazil is the biggest energy consumer in South

America, thus the output of the study will support in the design of energy evolution, through expansive and conservative policies for sustainable and long-term economic progress for BRICS countries.

The rest paper is organized as follow. Section 2 presents the economic-energy profile of BRICS countries. Section 3 presents the literature review. Section 4 presents a model including the estimation strategy, data, and variable description. Section 5 presents the research methodology. Section 6 provides the empirical results. Section 7 concludes the study and provide policy implications.

2 Profile of BRICS countries

In this section, we discuss both the economic growth and energy consumption overview of BRICS country, wherein the why BRICS question is answered off which the first part tackles the economic growth and its contribution from the global view, the link, and relationship between BRICS while the second part we analyze the share of energy consumption within BRICS countries, the impact and changes between renewable and non-renewable energy consumption.

2.1. Brief GDP pc, energy consumption, and population

According to World bank statistics also see Pant (2013), the BRICS represent 42% of the world`s population with China leading with 1.364 billion followed by India 1.236 billion, Brazil 203 million, Russia 146 million, and South Africa 55 million has the lowest population within the initiation as represented in **the Appendix A**. The group is also characterized by a huge share and influence of economic growth in the world wherein we denote that China reflect $10.4 trillion, Brazil with $2.3 trillion, India with $2.1 trillion, Russia with $1.9 trillion, and South Africa with $350 billion, the total GDP contribution accounts to $16.92 trillion (23% of the world GDP) for details see Shahbaz, Shahzad, Alam, & Apergis (2018).

Energy variables of this study use terajoule TJ as the measure. However, in this section we mentioned and explained different types energy sources such as mtoe, MW, Btu, and MMst as calculated within the countries and we also provide the equivalent to TJ to maintain the and sequence and the language of the study and for further measures and calculations of these types of energy sources see the **Appendix B**.

Fig. 1 represent the relationship between total final energy consumption and GDP per capita for BRICS group countries for our study period. It is apparent that there is a correlation between the two selected variables even though they grow steadily with the stagnation at the begging of 1990 and towards the end of the 90s. Seemingly both variables started to recover in the early 2000s and maintained the growth until 2008, this is evidence of the 2008 final crisis, which eventually affected all sector including the energy consumption.

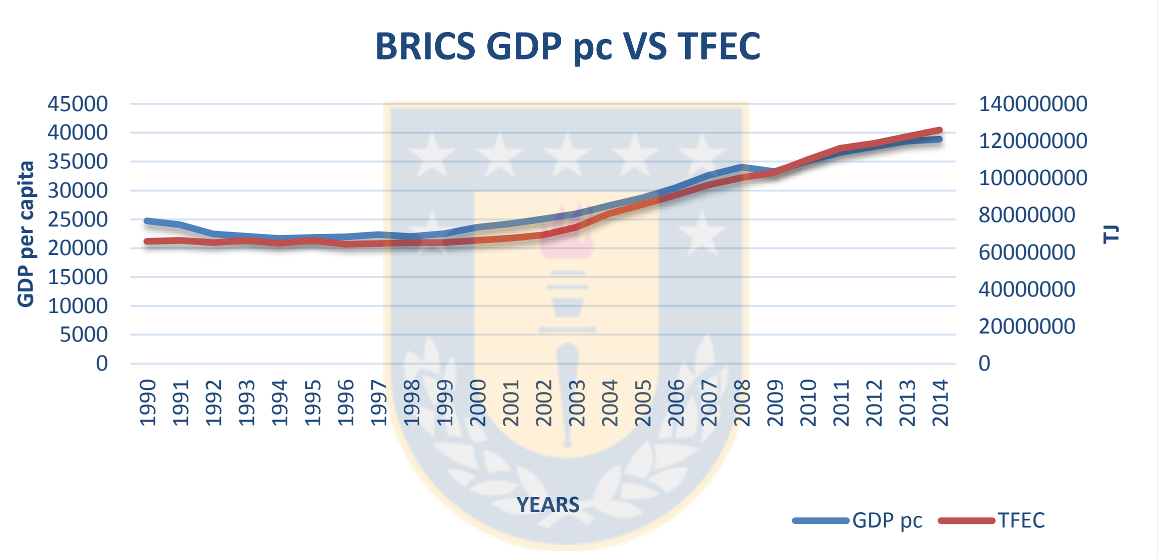


Figure 2.1: GDP per capita and Total final energy consumption.

Data sources: World Bank Indicators.

The total final energy consumption is the component of both renewable and non-renewable energy consumption, Fig. 2 depicts relations between these two types of energy for a selected timeframe in 1990, 2002, and 2014 respectively. The relationship is not constant as it is represented that in 1990 NREC had 73% and REC 27%, the grow however slightly interchanged between the variables from the 1990 to 2002 with NREC reducing to 72% and REC increasing to 28%. Many economies including South Africa and China encountered major energy crisis from the period of 2005 until 2013 thus also a huge decline of 8% from renewable energy consumption, even though there are many factors influencing such a trend while non-renewable energy remained the most consumed by the group.

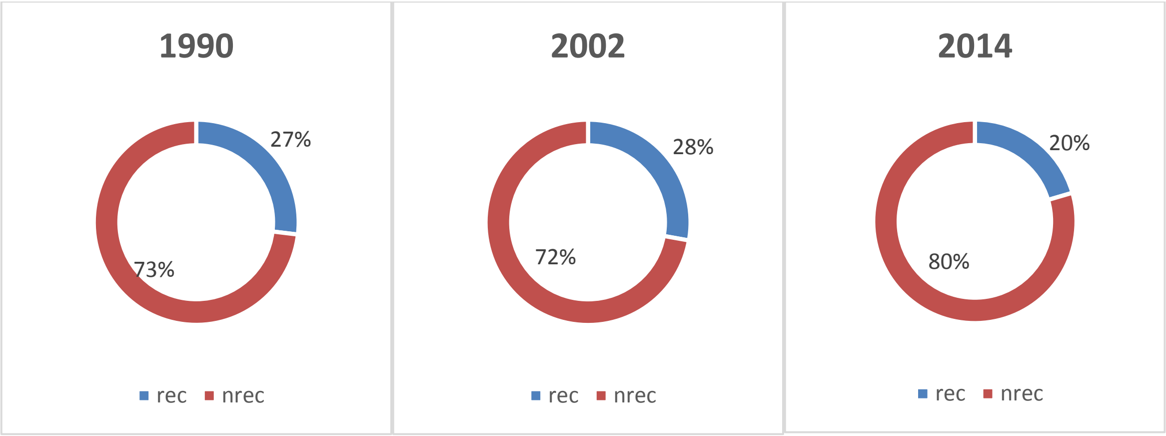


Figure 2.2: **REC VS NREC for BRICS.**

Data sources: World Bank Indicators.

2.2. BRICS countries affairs

In this section of the study, we also categorize BRICS countries into four regions namely West (Brazil), East (China and India), North (Russia), and South (South Africa). Begging with the West region in America, Brazil is known to be one of the most endowed country in energy resources in the world with wide range of variates from hydro-power, oil, gas, and biofuels and as stated before that Brazil is leading in Latin America with about 45% of its primary energy demand is from renewable energy sources IEA (2013).

In the begging of 2016 BRICS development Bank proclaimed the first loan projects of up to $811 million US dollars wherein $300 million was given to the Brazilian National Economic and Social Development Bank to boost Brazil's 600MW renewable energy power generation capacity BRICS Economic Think tank (2017).

BRICS’s operations infiltrate the new concept of "green finance", through the BRICS development Bank by providing renewable energy investment to stream into the fields like environmental protection, resource and energy conservation, highlighting the important role of finance to elevate the future energy arrangements, to stimulate economic growth and environmental protection complement each other, and to accomplish transformation and sustainable development of the BRICS’s economy, and finally to achieve green growth.

After a panel review and analysis, it is worth to break down the analysis by reviewing the energy profile of each country especially the relationship between renewable energy consumption and non-renewable energy consumption. We also extend the interest and focus up to the 2015 and 2016 respectively and below the subsection provide a detailed by kick-starting with Brazil.

2.3. Energy consumption profile in BRICS countries

2.3.1. Brazil

There has been a drastic change in Brazil`s energy consumption from non-renewable energy consumption to renewable energy consumption reflected through deteriorating consumption of oil (-5.6%), natural gas (-12.5%) and coal (-6.8%) wherein the offset increases in hydro (+6.5%), renewables in power (+18.4%) and nuclear (+7.5%). Oil consumption is Brazils major primary energy consumption with the proportion of 47%, in 2016 oil consumption has dropped by 150Kb/d to 3.0 Mb/d reaching the lowest in four years’ period. The correlated decline was also evident in natural gas consumption which accounts for 11% of energy consumption in Brazil and this shock is denoted by the decline from 37.5 mtoe to 32.9 mtoe in the year 2016. Hydro is the second primary energy consumption in Brazil after oil consumption accounting for 29% and in 2016 showed a massive increase from 5.5 mtoe to 87 mtoe, also another correlated increase by Renewables energy in 2016 increased by 3.0 mtoe of 1.3 mtoe which accounts for a proportion of 6% of energy consumption in Brazil. Finally, coal consumption which accounts for the same proportion as Renewables energy (6%) denoted a decline of 6.8% in 2016. (BP Brazil`s review, 2017).

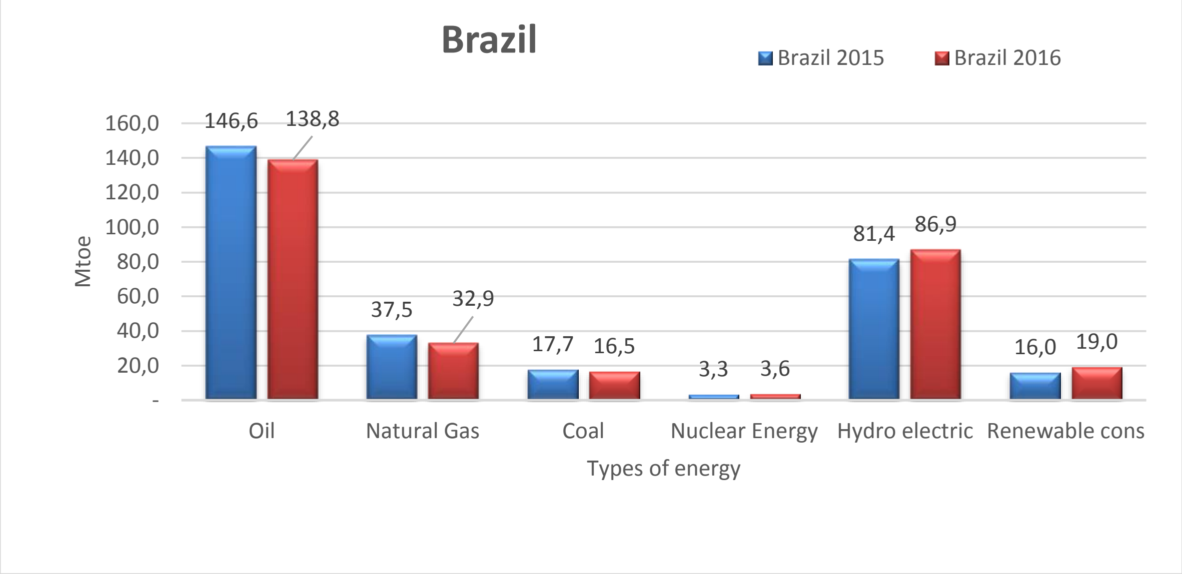


Figure 2.3: **REC VS NREC in Brazil 2015 and 2016**

Source: BP Statistical Review of World Energy June 2017 for Brazil.

2.3.2. Russia Federation

Russia is the fourth largest energy consumer after China, the USA, and India (two BRICS countries) in the world regardless of 1.4% decline in total final energy consumption equivalent to 7.7 mtoe in the year 2016. Consumption of gas energy is Russia`s major primary energy consumption accounting for the proportion of 52%, in the second place followed by oil which accounts for 22%, however, in 2016 oil consumption has increased by 2.1%. Coal consumption the third highest in Russia amounting to 13% after gas and oil denoted a decline of 5.5% in 2016, in contrast to that hydro has to increase its output by 9.5% in the same year. The correlated decline was also evident in CO2 emissions from energy consumption declined by 2.4% compared to the 10-year average of +0.2%(BP Russia`s review, 2017).

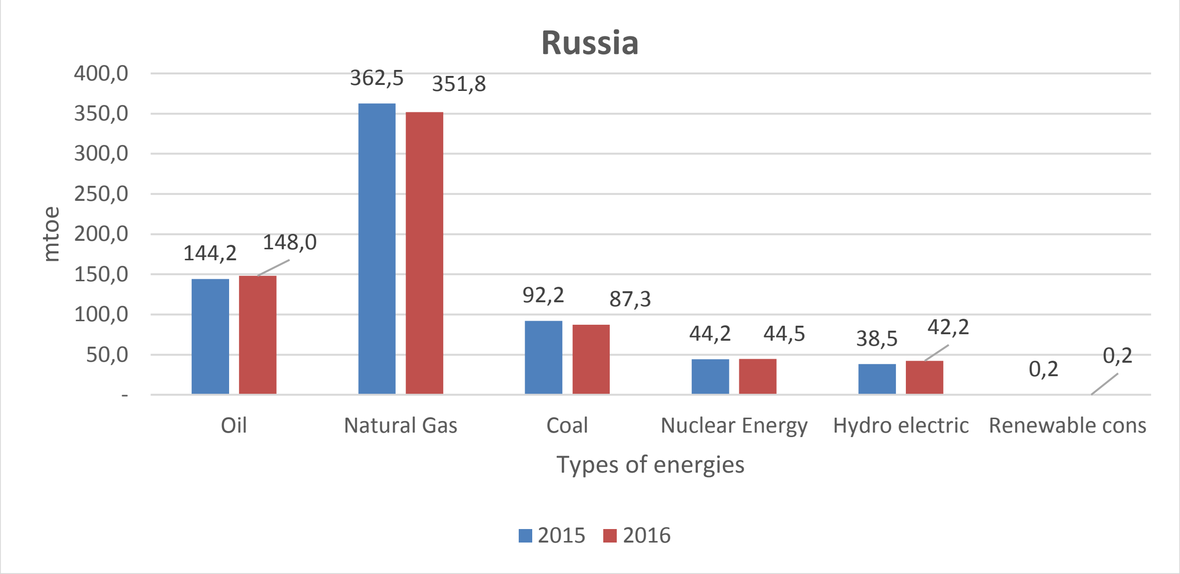


Figure 2.4: **REC VS NREC in Russia 2015 and 2016**

Source: BP Statistical Review of World Energy June 2017 for the Russian Federation

2.3.3. India

In 2016 India's global primary consumption share was recorded to have reached 5.5%, with increased consumption of oil (+7.8%), coal (+3.6%), gas (+9.2%) and renewables in power (+29.2%) outweighing the declines in hydro (-3.6%) and nuclear (-1.3%). In the same year, oil consumption increased by a record high of 325 Kb/d causing the country's primary energy consumption to increase for the third year in a row. In the same year, the country's gas consumption also increased following three years of decline. The coal consumption rate fell to 15 mtoe, which is nearly half of the country's 10-year average. In spite of this, the country's share of global coal consumption increased to 11% and renewable in power also increased by 29.2%, its largest growth ever making India the 7th largest renewable power generator. Alternatively, the energy intensity decreased by 1.3%, slower than the past 10-year average(BP India`s review, 2017).

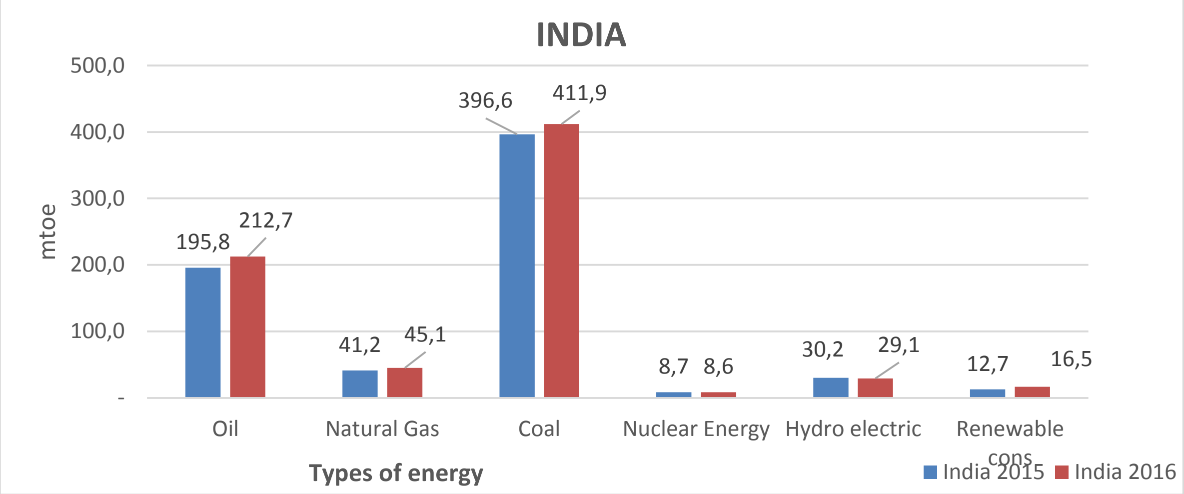


Figure 2.5: **REC VS NREC in India 2015 and 2016**

Source: BP Statistical Review of World Energy June 2017 for India

2.3.4. China

In 2016 China experienced energy consumption growth of 1.3% which is less than the country's 10-year average growth rate of 5.3%. Nonetheless, China still remains the largest energy consumer in the world with recorded global energy consumption at 23%, contributing 27% to the global energy demand growth in that year. In relations to fossil fuels, natural gas and oil led the consumption growth, whereas the use of coal decreased by 1.6%. Each and every one of the fossil fuels increased as rates lower than their 10-year average, whereas the country's energy mix constantly evolved. Making up 62% of the country's energy consumption coal stays the dominant fuel. Nonetheless, with a recorded share of 74% in the mid2000, this was undoubtedly the lowest share on record. In 2016 the country surpassed the USA and became the majority consumer of renewable power. This was due to the country's growth of 33.4% of consumption of renewable, making the Chinese renewable energy consumption account for 20.5% of the global total. This was a vast increase as compared with the 2% recorded in 2006 (BP China`s review, 2017).

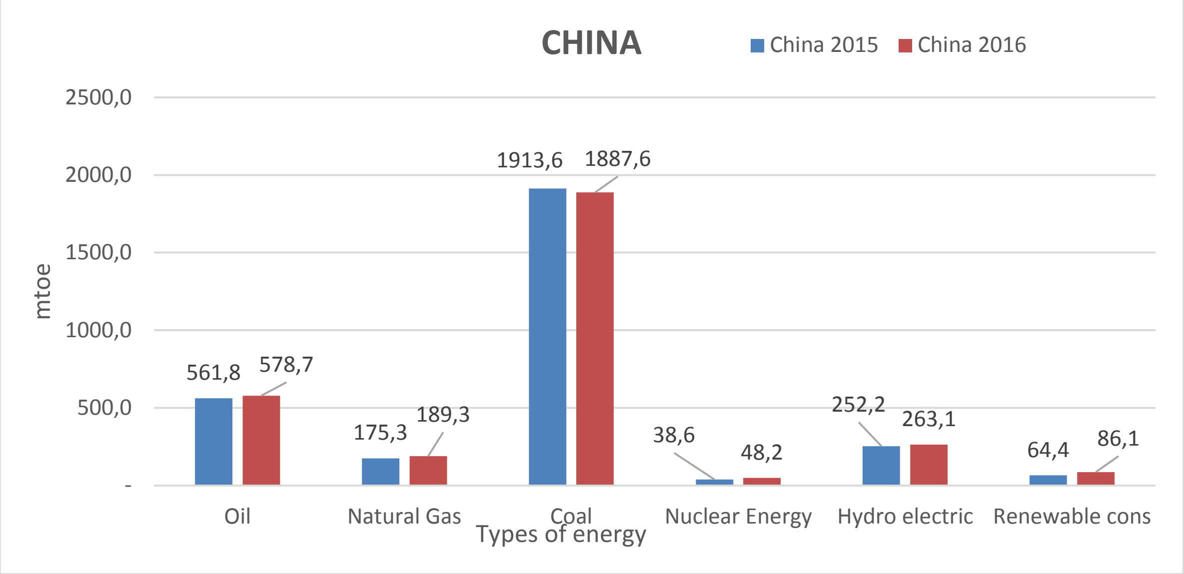


Figure 2.6: **REC VS NREC in China 2015 and 2016**

Source: BP Statistical Review of World Energy June 2017 (China)

2.3.5. South Africa

According to the Lin & Wesseh Jr. (2014), the economy of South Africa is heavily dependent on the energy sector which accounts for 15% of the country's GDP with coal being the dominant producer of the energy. The country has one of the lowest electricity prices in the world this is even after the recent increase in the electricity price. Eskom is generations of about 95% and supply of electricity in South Africa and the country has faced the massive and excessive demand for electricity in the past decade.

Eskom is one of the largest power utilities in the world and beyond generating electricity for South Africa, it also generates as much as two-thirds of the electricity for the African continent. It owns and operates the national transmission system. Eskom net generating capacity has 36 200 megawatts (MW) equivalent to 130.320000 TJ of which is primarily coal-fired (32 100 MW) and the company network is made up of more than 300 000 km of power lines, 27 000 km of which constitute the national transmission grid Odhiambo (2009b).

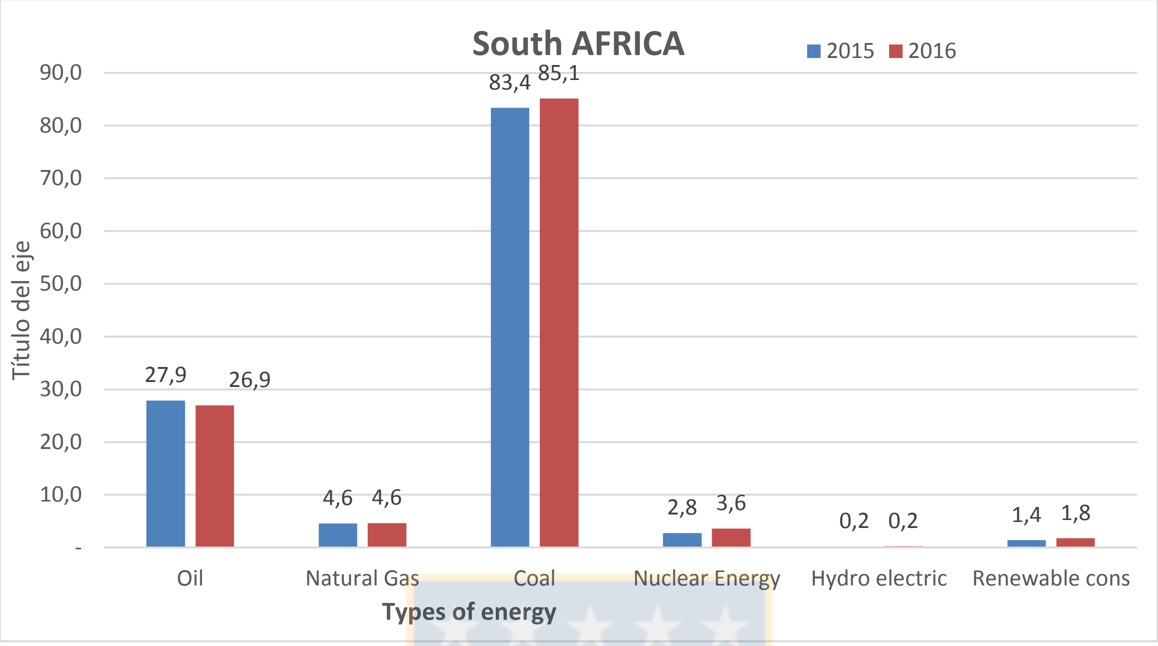


Figure 2.7: REC VS NREC in South Africa 2015 and 2016

Source**:** BP Statistical Review of World Energy June 2017 for South Africa

In 2008 the total energy consumption of South Africa amounted to an equivalent of 5.3 quadrillions Btu, while coal resources were estimated to be about 33 billion short tons, which accounted for 95% of the African continent's coal reserves and close to 4% of world reserves. Coal also is a significant feedstock for South Africa's synthetic fuel industry. Both the production and consumption of coal has maintained relatively stable levels over the past decade even though in 2010, there were estimations of 276 million short-tons and 201 million short tons (MMst) were produced and consumed respectively H. T. Pao & Fu (2013).

It has been evident that South Africa is energy intensive economy as in 2008 energy sector contributed about 15% to the GDP Menyah & Wolde-Rufael (2010a)and non-renewable energy mainly coal has been dominant thus there is a need to improve on the tendering and infrastructure investments in the renewable energy such as wind, concentrating solar power (CSP), solar PV in the Northern Cape province.

3 Brief literature review on energy-growth nexus

In this section, we review some several relevant studies which explored the energy-growth nexus, however in the mist of them all we identified that the approach has been more on causality than cointegration even though some tackled both as they focal framework. We categories this section into two by separating several empirical investigations based on panel data studies and simple time-series studies and the selection of studies is based on both interesting economies (BRICS countries) and relevant model application:

The theoretical literature has categorized the energy-growth nexus into four types of hypothesis off which they describe and classify the causality relationship and the most used econometric approach for such is the Panel VEC Model section 5 provide a detailed analysis of the approach.

The first is the **growth hypothesis** which postulates that energy consumption plays a vital role in economic growth both directly and indirectly as a complement to labor and capital in the production process, in other words, it's a unidirectional causality running from energy consumption to economic growth. The second is the **Conservation hypothesis** which supports that the reduction in energy consumption will have little to no effect on economic growth. Also, that an increase in real GDP causes an increase in energy consumption Odhiambo (2009a).

The third is the **feedback hypothesis** which argues bidirectional causality between energy consumption and economic growth. This relationship implies that there is a joint effect between energy consumption and economic growth. In other words, energy conservation has a negative effect on economic growth, and decreases in GDP have the negative impact on the level of energy consumption.

Finally, the **neutrality hypothesis** is supported by the absence of a causal relationship between energy consumption and economic growth. Which in other words denote that there is no correlation or rather causality relationship between energy consumption and economic growth.

We begin this by reflecting on the work by Belke, Dobnik, & Dreger (2011) who examined the causal association between (dis)aggregate renewable energy consumption, non-renewable energy consumption, and economic growth during the period of 1980–2009 for the case of **Brazil** within a production function framework including both labor and gross fixed capital. The output detects that there is a cointegration among the variables estimated and moreover, the Granger causality analyses output, at the aggregated level, support the growth hypothesis by reflecting a unidirectional causality relationship running from total renewable energy consumption to economic growth. Wherein the long-run causality from non-renewable energy consumption to economic growth reflects a bidirectional which proves evidence for the feedback hypothesis. At the disaggregated level, the causality tests analyses proved the presence of mixed results.

In the case of **Russia** H.-T. Pao, Yu, & Yang (2011) the study also supports feedback hypothesis as the output suggest a bidirectional relationship in modeling the dynamic relationships between the use of energy, pollutant emissions, and economic growth in Russia for the period of 1990-2007. Estimating both cointegration through Johansen test to detect the existence of long-run relationship among the variables and causality tests through ECM tests as both unit root testing and cointegration denotes that all variables are I(1) and cointegrated, ECM capture both short-run and long-run causality wherein the (ECT) term is optimal in correcting the disequilibrium in the cointegration for variables relationship.

Ohlan (2016) investigated the influence of renewable and non-renewable energy consumption on economic growth in **India** within the energy consumption–growth nexus over the period 1971-2012. The outcome, however, firstly confirms the existence of a long-run equilibrium relationship among the variables and secondly that the long run elasticity of renewable energy consumption and economic growth is not significant while the non-renewable energy consumption is positive and significant for the economic growth of India**.** Finally, the causality relationship supports feedback hypothesis wherein the relationship is found to be bidirectional both in short-run and long-run between non-renewable energy consumption and economic growth. Paul & Bhattacharya (2004) also studied the causality relationship between energy consumption and economic growth in India for the period 1950–

1996. Applied Engle-Granger cointegration approach combined together with the standard Granger causality test and the findings also support and confirms the feedback hypothesis.

In the case of **China** Lin & Moubarak (2014) findings also support feedback hypothesis as the output suggest a bidirectional causality relationship in the long-run by investigating the causality relationship between economic growth and renewable energy consumption in China for the period of 1977-2011, applying two different cointegration tests namely ARDL and Johansen cointegration in a multivariate framework analysis including both labor and carbon dioxide and also estimated Granger causality for the direction of causality.

In contrast to findings by Belke et al. (2011) which we have explained above, Odhiambo (2009b) investigated the causality in trivariate framework between energy consumption and real economic growth in **South Africa** supports the feedback hypothesis by finding a bidirectional causality between electricity consumption and economic growth and also employment Granger causes economic growth for both short-run and long-run formulation. In the case of South Africa, Menyah & Wolde-Rufael (2010b) study examined the long-run and the causal relationship between economic growth, pollutant emissions, and energy consumption for the period 1965–2006. Applying the bound test to cointegration and the results denote a unidirectional causality running from pollutant emissions to economic growth and energy consumption to economic growth. Lin & Wesseh Jr. (2014) reexamined energy-growth nexus in South Africa with the same variables but different approach applying a nonparametric bootstrap method to reassess evidence supporting Granger causality and the results confirm a long-run unidirectional causality from energy consumption to economic growth.

The empirical results are mixed across countries and such is evident from the various panel data studies. Shafiei & Salim (2014) study explored the determinants of CO2 emissions using the STIRPAT model and GMM) method to examine the long-run and short-run Granger causalities between CO2 emissions total population, population density, GDP per capita, urbanization, industrialization, the contribution of services to GDP and renewable and non-renewable energy consumption for OECD countries data from 1980 to 2011. The empirical findings denote that non-renewable energy consumption increases CO2 emissions, whereas renewable energy consumption decreases CO2 emissions.

The Nicholas Apergis & Payne (2009b) study also panel of twenty OECD countries over the period 1985–2005 examined the relationship between renewable energy consumption and economic growth within a multivariate framework and a panel cointegration and error correction model is employed to infer the causal relationship. The Pedroni (1999) panel cointegration test denote a long-run equilibrium relationship between real GDP, renewable energy consumption, real gross fixed capital formation, and the labor force with the respective coefficients positive and statistically significant. The Granger-causality findings support feedback hypothesis by indicating bi-directional causality between renewable energy consumption and economic growth.

Bhattacharya, Reddy, Ozturk, & Bhattacharya (2015) investigated the effects of renewable energy consumption on the economic growth of 38 top renewable energy consuming countries in the world (wherein four of these are BRICS countries excluding Russia) to illuminate the growth process between 1991 and 2012. Applying both Pedroni (1999) and Kao (1999) to detect the cointegration equilibrium relationship and the results denote that renewable energy consumption has a significant positive impact on the economic growth for 57% in the long-run output elasticity.

Al-Mulali, Fereidouni, & Lee (2014) examined the effect of renewable and non-renewable energy consumption on economic growth in 18 Latin American countries for the period of 1980-2010. Pedroni (1999) panel cointegration test denotes the long-run equilibrium relationship and the VECM Granger causality results support the feedback hypothesis between the variables. Nicholas Apergis & Payne (2010b) investigated the causal relationship between renewable energy consumption and economic growth for 13 countries within Eurasia over the period 1992–2007 within a multivariate panel data framework. The findings support the feedback hypothesis by indicating the bi-directional causality between renewable energy consumption and economic growth in both the short-run and long-run.

Esso & Keho (2016) examined the energy-growth nexus for a sample of 12 Sub-Sahara African countries for the period of 1971-2010. In the long-run causality confirms, economic growth and energy consumption affect CO2 emissions in South Africa, Nigeria, Benin, Cote d'Ivoire, Togo, and Senegal in a study where both cointegration and Granger causality were modeled for the existence of long-run relationship and direction of causality among the variables. Findings also support the feedback hypothesis wherein the relationship is found to be a bi-directional causality between economic growth and CO2 emissions in the short- run for Nigeria.

Table 3.1 provide the list of empirical studies which were in several approaches can be utilized to address the issues of Cointegration and causality, which have been noted in the energy-growth causality literature.

Table 3.1: Summary of empirical studies on Growth and Energy Consumption nexus.

Author(s)/ Study	Methodology	Country(ies)	period	Variables	Hypothesis
Nicholas Apergis & Payne (2011)	Panel cointegration and VECM	13 Eurasia countries,	1992–2007	REC, GDP, L, K	Feedback hypothesis
Nicholas Apergis & Payne (2009a)	VECM and Panel Cointegration	Commonwealth of Independent States,	1991-2005	REC-EC, K, L	Growth and Feedback hypothesis
Belke et al. (2011)	Panel cointegration, VECM, Granger causality	25 OECD,	1981-2007	REC & GDP	Feedback hypothesis
H. T. Pao & Fu (2013)	Johansen's cointegration test and Error Correction model	Brazil,	1980-2010	GDP, REC, NREC, TFEC, K, L	Feedback hypothesis
(N Apergis & Payne, 2010a)	Panel cointegration, VEC and Granger causality	Central America,	1980-2006	REC, K, L	
Levin & Lin (1992)	Panel cointegration and causality	Middle-Income countries,	1971-2005	REC-GDP	
Oguz & Alper (2013)	ARDL and Toda- Yamamoto	Turkey,	1990-2010	REC, GDP, K, L	Conservation hypothesis
Kahia, Aïssa, & Lanouar (2017)	Panel cointegration and VECM	MENA countries	1980-2012	GDP, REC, NREC, L, K	
Sebri & Ben-Salha (2014)	Panel cointegration and VECM	BRICS countries	1971-2010	GDP, REC, CO2, Trade	
Adams, Klobodu, & Opoku (2016)	Panel VAR, GMM	Sub-Saharan Africa	1971-2013	EC, GDP, Political regime	Feedback hypothesis
Tiwari (2016)	Panel VAR, GMM	Europe & Eurasian countries.	1965-2009	GDP,REC, NREC, CO2	
Marques, Fuinhas, & Marques (2017)	ARDL panel	43 global countries	1971-2013	EC, GDP, Political regime	Feedback hypothesis
Abdulnasser & Irandoust (2005)	LEVERAGED BOOTSTRAP	Sweden	1965-2000	GDP, EC	Neutral hypothesis
Odhiambo (2009a)	Johansen's cointegration test and Error Correction model	South Africa	1990-2010	GDP, REC, L,	Feedback hypothesis
Saboori & Sulaiman (2013)	ARDL and VECM	ASEAN countries	1971-2009	GDP, EC, CO2 emissions	Feedback hypothesis

4 Model and Data

In this study, we employ the framework proposed in Baltagi & Kao (2000) panel cointegration modeling and Maddala & Wu (1999) for the choice variables and model of neo-classical aggregate production technology where labor, capital, and energy consumption are treated as separate inputs.

$$Y_t = f(K_t,\ L_t, EC_t) \tag{1}$$

$$where: EC_t = REC_t\ NREC_t\ TFEC_t$$

We estimate annual time series data from 1990 to 2014 and the data was obtained from the World Bank Development Indicators and IEA statistics for all the five BRICS countries (Brazil, Russia, India, China, and South Africa). The econometric framework includes GDP per capita Y in billions of constant 2010 US$, gross fixed capital formation K in billions of constant 2010 US$, total labor force L in millions, non-renewable energy consumption NREC a component of fossil fuel energy which comprises of coal, oil, petroleum and natural gas terajoule (TJ), Renewable energy consumption REC this variable includes energy consumption from all renewable resources such as hydro, solid biofuels, wind, solar, liquid biofuels, biogas, geothermal, marine and waste, measured in terajoule (TJ) , and the last one is Total final energy consumption TFEC which is the is the summation of both REC and NREC terajoule (TJ). All variables are conveyed in natural logarithm to correct the heteroscedasticity.

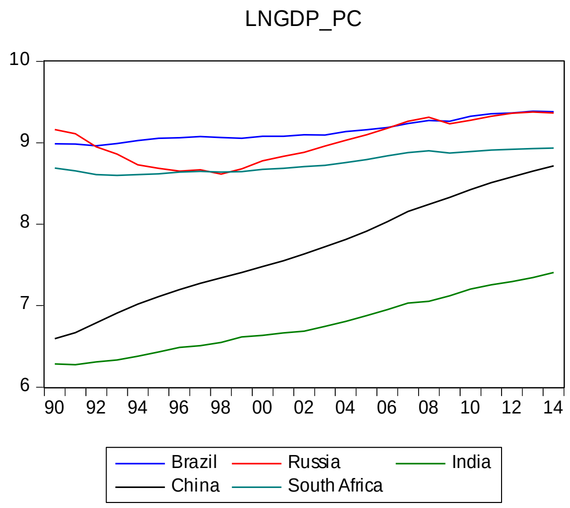
Table 4.1 However, represents the descriptive statistical analysis of the variables such as economic growth per capita, renewable energy consumption, non-renewable energy consumption, and total final energy consumption respectively reflecting together with their mean, and standard deviation. The mean values are positive for all countries variables, we denote that Brazil has the highest mean for GDP per capita (9473.84) followed by Russia (8499.54), in third place in South Africa with (6361.06) while China and India reflect lower values such as 2645.46 and 929.63 this also evident in the fact that both India and China have the largest population numbers within the BRICS group thus their GDP per capita is low. With regards to renewable energy consumption, China has the highest mean value (9949632) followed by China with (6572159), and India (621094.4). With regards to non-renewable energy consumption, China lead with a mean value of (33557541) followed by Russia (16495791) and third is India with (7360215) this is evidence that all these countries are within the top four high energy consumption in the world.

Table 4.1: Descriptive Statistics

	Mean	Std. dev.		Mean	Std. dev.
Panel A: GDP pc			**REC**		
Brazil	9473.84	1341.06		2891786	640870.9
Russia	8499.54	2182.42		621094	127255
India	929.63	348.16		6572159	705696
China	2645.46	1887.16		9949632	1229873
South Africa	6361.06	787.94		403628	49071
Panel B: NREC			**TFEC**		
Brazil	3470542	887419.7		6362328	1499484
Russia	16495791	260046		17116885	2723703
India	7360215	3016438		13923274	3712401
China	33557541	1.62e+07		43507173	17362330
South Africa	1952180	337405.7		2355807	384192.6

Source: Own preparation using Stata

The following diagrams figure 4.1 denote the graphical representation of the variables in the level I(0) and the first order I(1) from 1990 to 2014 for all five BRICS countries, however we first denote that all variables were affected by the 2008 financial crisis as they reflect the downfall irrespective of the country even though the impact is less reflected in the raw data than the first difference data, and Russia GDP reaches the lowest compared to other countries in I(1). In **figure 4.1** it does appear that all variables tend to move together, however the fact variables tend to move together does not in way for time series infer or prove symmetric relationship between the variables hence we then employ the advanced techniques (Cointegration tests and FMOLS and DOLS) to prove that there is both a short-run and long-run relationship between the variables.


LNGDP_PC
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90 92 94 96 98 00 02 04 06 08 10 12 14
Brazil
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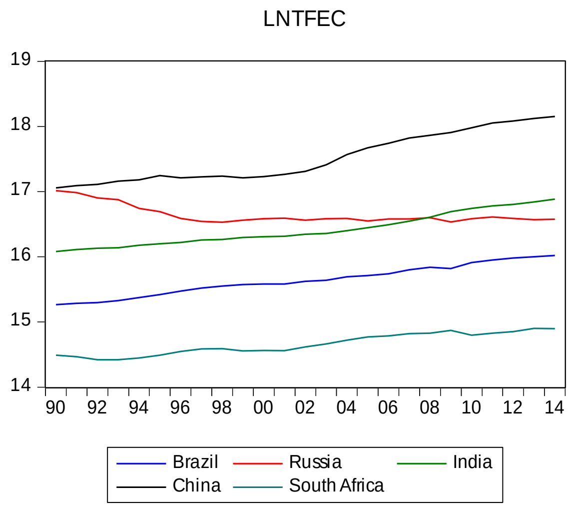
South Africa


LNTFEC
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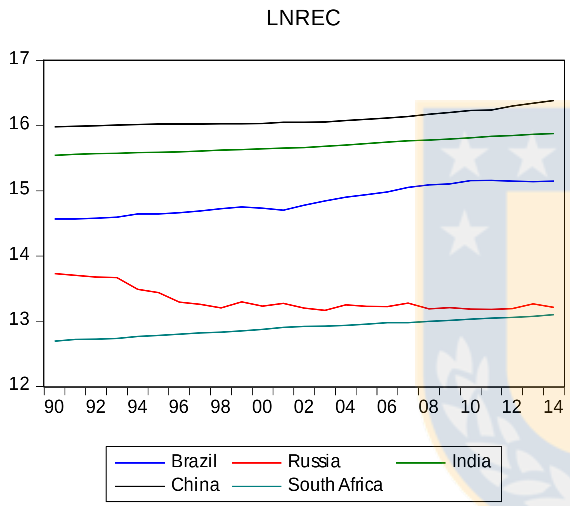
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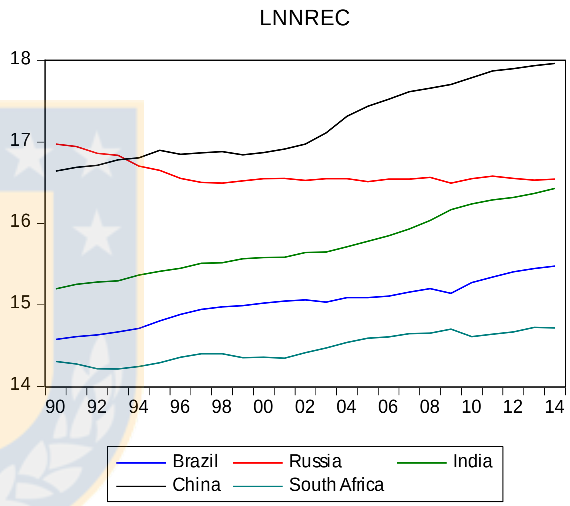
LNNREC
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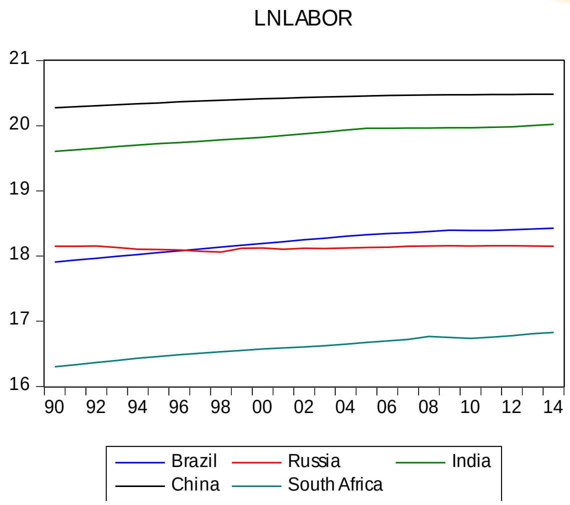
South Africa


LNLABOR
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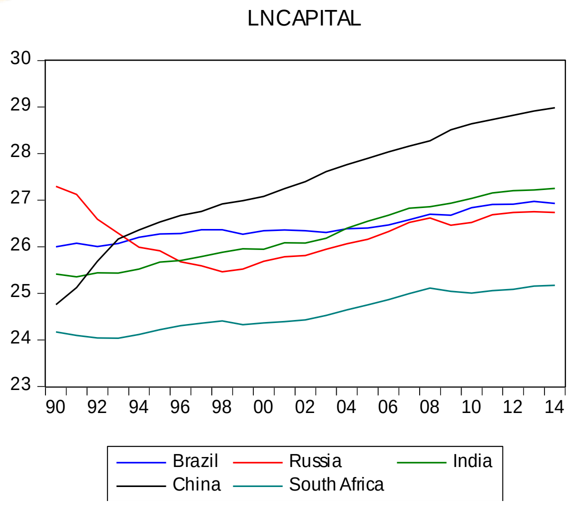
90 92 94 96 98 00 02 04 06 08 10 12 14
Brazil
Russia
India
China
South Africa


LNCAPITAL
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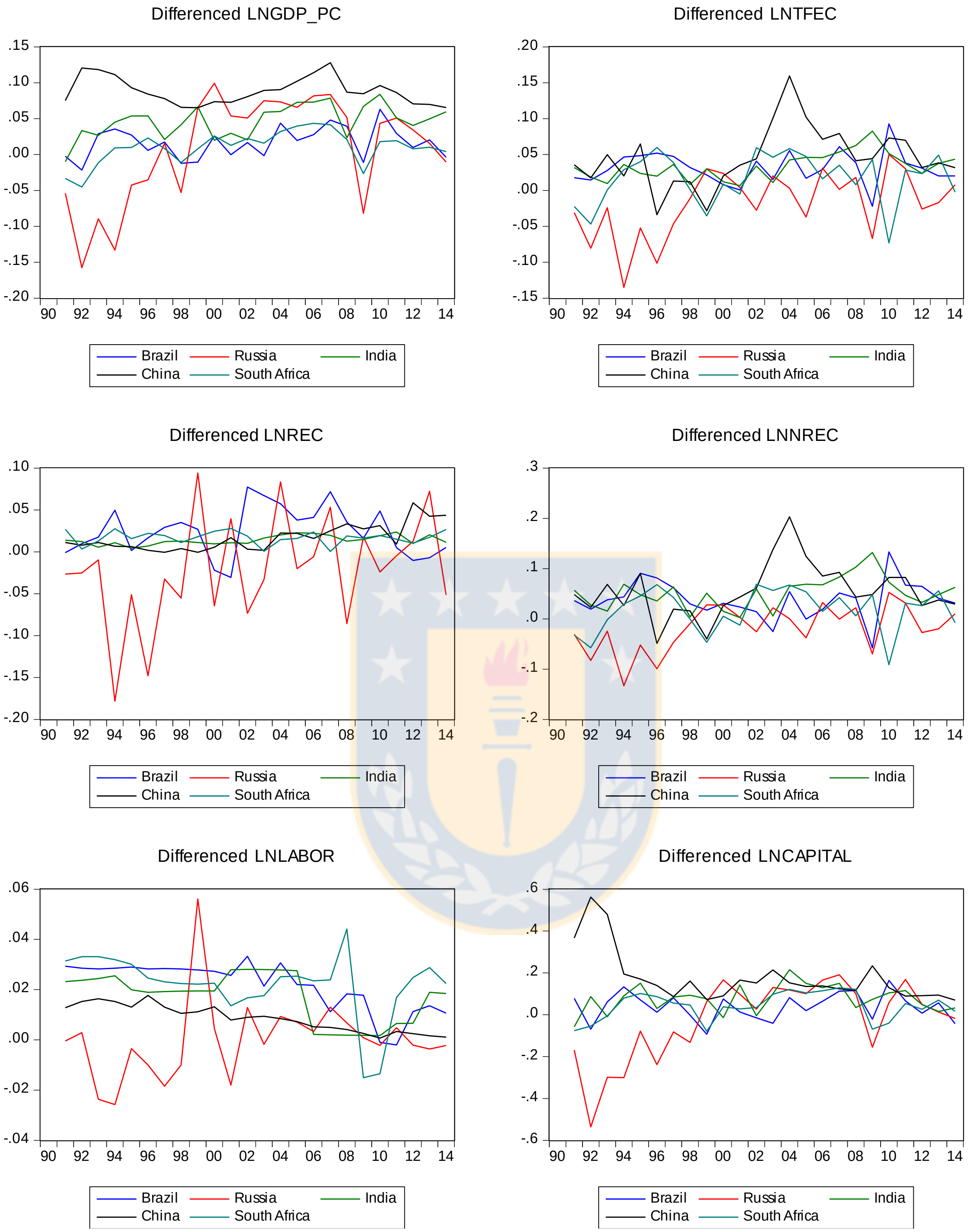
25
24
23
90 92 94 96 98 00 02 04 06 08 10 12 14
Brazil
Russia
India
China
South Africa


Differenced LNGDP_PC

Differenced LNTFEC

Differenced LNREC

Differenced LNNREC

Differenced LNLABOR

Differenced LNCAPITAL

Figure 4.1: The first difference I(1) plots of the lnGDP pc, lnK, lnL, lnREC, lnNREC, lnTFEC, 1990-2014

Source**:** Own preparation using EViews 8

5 Methodology

This section of the paper is categorized into three major subsection (i) where we estimate the panel unit testing (such as LLC, Breitung, ADF, and PP-Fisher tests), with the objective that all variables are integrated of order one I (1), then if such an assumption is met, secondly (ii) we estimate panel cointegration tests through Pedroni (1999) and Kao (1999), techniques to detect the existence of long-run relationship among the variables, if the outcome detect that the variables are cointegrated we also follow Pedroni (2000) approach by estimating FMOLS for the and finally (iii) we the estimated granger causality through VECM and more detailed explanation is presented below and this methodology approach is influenced by these studies N Apergis & Payne (2010b) and Bhattacharya, Reddy, Ozturk, & Bhattacharya (2016) :

In this study, however, the most important approach which is different from all other BRICS studies is that we apply the approach by Inglesi-Lotz (2015), by estimating three different models independently and such is optimal to ensure robust results:

Model 1

- Depended variable: GDP
- Regressors: Capital, Labor, and renewable energy consumption (REC)

Model 2

- Depended variable: GDP
- Regressors: Capital, Labor, and non-renewable energy consumption (NREC)

Model 3

- Depended variable: GDP
- Regressors: Capital, Labor, and total final energy consumption (TFEC)

5.1 Panel Unit root tests

Researchers have tackled and categorized panel unit tests into two generations, wherein the first generation allows the cross-sectional independence (panel unit root tests without structural breaks) and the second generation allows cross-sectional dependence (panel unit root tests with structural breaks)

Unit root testing for panel data studies has been tackled it differently by researchers applying and focusing on different approaches, thus (Maddala & Wu, 1999) test approach is more generally applicable, allows for individual specific effects as well as dynamic heterogeneity across groups (countries), and requires N=T → ∞ as both N (the cross-section dimension) and T (the time series dimension) tend to infinity. The tests proposed by Im, Pesaran, & Shin (2003) do not accommodate heterogeneity across groups such as individual specific effects and different patterns of residual serial correlations. For more analysis see Breitung & Lechner (1998), Maddala & Wu (1999)

In this study, however, we adopt both approaches by Maddala & Wu (1999) and Im et al. (2003) by applying both cross-sectional independence tests for panel unit testing which permit for heterogeneous autoregressive coefficients and homogeneous respectively. Wherein cross-sectional independence tests, can be also split into two subgroups: (a) heterogeneous[1] and (b) homogeneous[2] cases thus in this paper for this category we applied LLC, Breitung for heterogeneous and ADF and PP-Fisher for homogeneous however only ADF is demonstrated in this study and for the rest of the tests see Kahia et al. (2017) and Pedroni (1999).

Bellow, we present ADF as stated before:

$$y_{it} = \rho_i y_{it} + \emptyset_i X_{it} + \varepsilon_{it} \tag{2}$$

Where: $\varepsilon_{it} = \sum_{j=1}^{pi} \varphi_{it}\varepsilon_{it-j} + u_{it}$ proposed by Im et al. (2003) averages the augmented Dickey-Fuller (ADF) unit root tests while allowing for different orders of serial correlation thus the equation 1 results into the following:

$$y_{it} = \rho_i y_{it} + \emptyset_i X_{it} + \sum_{j=1}^{pi} \varphi_{it}\varepsilon_{it-j} + u_{it} \tag{3}$$

Where i=1,…, N for each country in the panel; t=1, T refers to the time period; X_{it} represents the exogenous variables in the model including fixed effects or individual time trend; ρ_i the

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[1] For the heterogeneous test we estimated ADF supported by Maddala & Wu (1999) and PP-Fisher supported by Im et al. (2003);

[2] For homogeneous panel unit test we estimated Breitung (1999) supported by Levin & Lin (1992) and LLC by Banerjee (1999)

autoregressive coefficients; and ε_{it} the stationary error terms. The null hypothesis is that each series in the panel contains a unit root (H0: ρ_i =1∀i). The alternative hypothesis is that at least one of the individual series in the panel is stationary (HA: ρ_i <1). The panel unit root testing is represented in the table (4).

5.2 Panel Cointegration tests

In this study, we apply a panel cointegration test in the multivariate frame. The cointegration concept resembles the co-movement between two or more variables in the long-run and this is applied to determine the existence of the long-run relationship between variables. However, we apply two tests of panel cointegration namely Pedroni (1999) and Kao (1999) tests proposed by McCoskey & Kao (1998), and Maddala & Wu (1999), respectively.

The Pedroni (1999) and Kao (1999) tests are grounded on Engle-Granger two-step residual-based cointegration tests. Wherein Pedroni (1999) which is comprehensive proposes numerous tests for cointegration that allow for heterogeneous intercepts and trend coefficients across cross-sections. However, bellow we separately explain these tests:

5.2.1 Pedroni panel cointegration tests

This cointegration framework by Cowan et al. (2014 Onishi et al. (2012 Sebri & Ben-Salha (2014) provides cointegration tests for both heterogeneous and homogenous panels with seven tests based on seven residual-based statistics. Of the seven tests, the panel v-statistic is a one-sided test where large positive values reject the null hypothesis of no cointegration whereas large negative values for the remaining test statistics reject the null hypothesis of no Cointegration: $H_o\colon\ \rho_i = 1\ \forall i$ tested against alternative hypothesis: $H_1\colon\ \rho_i < 1\ \forall i$. Four of these statistical tests such as panel ν, panel ρ, panel PP and panel ADF-statistic pool the autoregressive coefficients across different countries for the unit root tests on the estimated residuals, while the group tests such as group r, group PP, and group ADF-statistics are based on the between dimension approach. The Pedroni (1991) test includes individual intercept and trend.

$$Y_{it} = \propto_{it} + \theta_i + \beta_{42} EC_{it} + \beta_{44} K_{it} + \beta_{45} L_{it} + \varepsilon_{it} \quad (4)$$

$$for\ i = 1, \dots, N;\ t = 1, \dots, T$$

$$Where: EC_{it}\ denote\ REC_{it}, TFEC_{it}, NREC_{it}$$

Where T denotes the number of observations over time, N denotes the number of individual members in the panel namely five BRICS countries, we also added the deterministic time trends denoted $\propto_{it}$ which are specific to each and every individual member of the panel and the parameters θ_1 is the member-specific intercept or fixed effects which is also allowed to vary across the individual members. As stated that EC represents REC, NREC, and TFEC for each equation estimated separately.

Thus the estimated residuals with the autoregressive term ρ_i:

$$\varepsilon_{it} = \rho_i \varepsilon_{it-1} + w_{it} \quad (5)$$

5.2.2 Kao panel cointegration test

This panel cointegration test approach is the artwork of Kao (1999), which proposes the Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF), where the vectors of cointegration are homogeneous and pooled regression permitting individual fixed effects across the individual member of the panel.

Consider $\hat{\varepsilon}_{it}$ to be the estimated residuals from the following equation (6).

$$Y_{it} = \vartheta_i + \beta_i X_{it} + \varepsilon_{it} \quad (6)$$

Where the ADF test is obtained by estimating the following equation (7).

$$\hat{\varepsilon}_{it} = \widehat{\gamma\varepsilon}_{it-1} + \sum_{j=1}^{p} \rho_j \Delta\hat{\varepsilon}_{it-j} + \omega_{itp}$$

(7)

Where γ is applied such that the residuals ω_{itp} are serially uncorrelated with the null hypothesis of no cointegration. For more detail explanation about ADF and DF tests for this panel cointegration test seen Baltagi (2005), Baltagi & Kao (2000), and McCoskey & Kao

(1998) . The advantage of this test is that the cross-sections are assumed to be independent for each country within the BRICS group and it allows the presents of heteroscedasticity across the cross-section Hoang (2006).

5.3 Panel FMOLS and DOLS

The following step is to estimate the long-run relationship using two robust methods such as fully modified ordinary least squares (FMOLS) proposed by Phillips & Hansen (1990) and dynamic ordinary least squares (DOLS) proposed by Saikkonen (1991). The use of DOLS is optimal in that it essentially eradicates the asymptotic inefficiency of the OLS estimator through the using all the stationary information of the system to explain the short-run dynamics of the panel cointegration regression. While on the hand FMOLS approach is optimal to deal with endogeneity between the regressors.

We apply the knowledge from the previous unit root tests that variables are not stationary at level (0) but are integrated of order one (I). Therefore we adopt approach by Banerjee (1999) a heterogeneous panel cointegration test FMOLS and DOLS[3], which allows for cross-section interdependence with different individual effects, not only the dynamics and fixed effects to differ across members of the panel, but also they permit the cointegration vector to be heterogeneous across the member under the alternative hypothesis.

5.4 Granger causality test

This last part of the methodology is determined mainly by the results of cointegration, wherein the optimal approach to estimate if there is no cointegration among the variables is panel VAR model, whereas if the variables are cointegrated panel VECM Pesaran, Pesaran, Shin, & Smith (1999) is the optimal approach to detect the causality direction. In this study

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[3] The use of the FMOLS approach is motivated by the empirical findings of Banerjee (1999) who shows that the FMOLS or DOLS estimates are asymptotically equivalent for a sample size higher than 60 observations (in this paper the panel dataset comprises 125 observations).

Engle & Granger (1987) two-step procedure is applied to detect the direction of causality and we first estimate the long-run model through the approach as specified in Eq. (4) to acquire the estimated residuals from the long-run estimation. Next, the lagged residuals from Eq. (4) serve as the error correction terms for the dynamic error correction model as follows:

$$\Delta lnGDP = \alpha_{1j} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnGDP_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnL_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnK_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnEC_{t-i} + \delta_1 \varepsilon_{t-1} + \mu t$$

(8.1)

$$\Delta lnK = \alpha_{2j} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnGDP_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnL_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnK_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnEC_{t-i} + \delta_2 \varepsilon_{t-1} + \mu t$$

(8.2)

$$\Delta lnL = \alpha_{3j} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnGDP_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnL_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnK_{t-i} + \sum_{i=1}^{q} \varphi_{2i} \Delta lnEC_{t-i} + \delta_3 \varepsilon_{t-1} + \mu t$$

(8.3)

$$\Delta lnEC = \alpha_{4j} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnGDP_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnL_{t-i} + \sum_{i=1}^{q} \varphi_{i1} \Delta lnK_{t-i} + \sum_{i=1}^{q} \varphi_{2i} \Delta lnEC_{t-i} + \delta_4 \varepsilon_{t-1} + \mu t$$

(8.4)

Where Δ denotes the 1st difference operator, μ is the serially uncorrelated error term, q is the lag-length, δ is the speed of adjustment toward the long-term equilibrium and the short-run causality relationship is examined by estimating jointly the significance of the coefficients associated to the variables in first difference variables including their lags and i(i= 1,…, s) represent the optimal lag length selection using the Schwarz Information Criterion (SIC). EC represents REC, NREC, and TFEC for each equation estimated separately.

6 Empirical results and discussion

As shown in **table 6.1** We fail to reject the null hypothesis of a unit root (non-stationary) at the level I(0) for all variables for these tests LLC's test, Breitung t-stat and IPS-W statistics, IPS, and ADF-Fisher respectively. While at the taking the first difference we reject the null hypothesis of non-stationary at 1%, and 5% for all variables and for all tests. That all variables are stationary at first difference, thus support what we anticipated with the objective to estimate the cointegration tests with all variables integrated of order one I(1).

Table 6.1: Unit root Panel BRICS-countries analysis

Variables	LLC	IPS	ADF-Fisher	PP-Fisher	B
Y	5.497	-2.034	0.515	0.518	1.096
ΔY	-2.053**	-1.785**	18.139*	19.264**	-1.597*
REC	4.627	4.579	4.829	4.608	4.159
ΔREC	-1.359*	2.1241**	15.689	34.067***	-1.759**
NREC	-0.252	-0.763	7.943	8.671	1.441
ΔNREC	-4.137***	-2.820**	37.771***	72.194***	-1.494*
TFEC	4.007	2.124	3.342	4.076	0.264
ΔTFEC	-2.403***	20.198**	38.103***	-2.821***	-2.8212**
K	4.379	1.166	1.051	1.319	0.425
ΔK	-5.224***	-4.331***	40.257***	42.547***	-1.571*
L	1.0529	-1.574*	1.791	0.799	3.798
ΔL	-2.776***	-1.316*	29.345***	31.277***	-2.531***

Notes: Δ=First difference operator. B, and Ps denote the Breitung, and the Pesaran unit root tests, respectively. ***, **, and *represent the significance at the 1%, 5%, and 10% level, respectively. (.): Probabilities

Source: Own preparation using EViews 8

Table 6.2. reflects the results of the Pedroni (1999) panel cointegration test. The outcomes denote that at least four statistics are significant at 1% while group rho-statistic is significant at 10%, thus, rejecting the null hypothesis of no cointegration. The outcomes also confirm the existence of a long-run relationship between the independent variables namely renewable energy consumption, labor force, gross fixed capital, and the dependent variable LGDP per capita.

Table 6.2: Pedroni Panel cointegration test results: (REC)

H1: (within-dimension)			**H1: (between-dimension)**	
	Statistic	Weighted Statistic		Statistic
Panel v-Statistic	0.656	-1.379	Group rho-Statistic	0.535*
Panel rho-Statistic	-1.027	0.084	Group PP-Statistic	-4.651***
Panel PP-Statistic	-4.116***	-4.372***	Group ADF-Statistic	-4.023***
Panel ADF-Statistic	-4.062***	-3.963***		

Notes: Trend assumption include deterministic intercept and trend. Lag selection: Automatic based on SIC with a max lag of 3. Of the seven tests, the panel v-statistic is a one-sided test where large positive values reject the null hypothesis of no cointegration whereas large negative values for the remaining test statistics reject the null hypothesis of no cointegration. *** Denote rejection of the null hypothesis of no cointegration at 1% significance level.

Source: Source: Own preparation using EViews 8

Table 6.3 reflects the results of the Pedroni (1999) panel cointegration test. The outcomes denote that at least five statistics are significant at 1% while group rho-statistic is significant at 10%, thus, rejecting the null hypothesis of no cointegration. The outcomes confirm the existence of a long-run equilibrium relationship between the independent variables namely non-renewable energy consumption, labor force, gross fixed capital, and the dependent variable LGDP per capita.

Table 6.3: Pedroni Panel cointegration test results: (NREC)

H1: (within-dimension)			**H1: (between-dimension)**	
	Statistic	Weighted Statistic		Statistic
Panel v-Statistic	22.059***	10.336***	Group rho-Statistic	1.061*
Panel rho-Statistic	0.496	-0.229	Group PP-Statistic	-3.637***
Panel PP-Statistic	-1.072	-2.601***	Group ADF-Statistic	-3.771***
Panel ADF-Statistic	-2.268**	-2.970***		

Notes: Trend assumption include deterministic intercept and trend. Lag selection: Automatic based on SIC with a max lag of 3. Of the seven tests, the panel v-statistic is a one-sided test where large positive values reject the null hypothesis of no cointegration whereas large negative values for the remaining test statistics reject the null hypothesis of no cointegration. *** Denote rejection of the null hypothesis of no cointegration at 1% significance level

Source: Own preparation using EViews 8.

Table 6.4. reflects the results of the Pedroni (1999) panel cointegration test. The outcomes denote that at least four statistics are significant at 1% while panel rho-statistic is significant at 10%, thus, rejecting the null hypothesis of cointegration. The outcomes also confirm the existence of a long-run equilibrium relationship between the independent variables namely total final energy consumption, labor force, gross fixed capital, and the dependent variable LGDP per capita.

Table 6.4: Pedroni Panel cointegration test results (TFEC)

H1: (within-dimension)			**H1: (between-dimension)**	
	Statistic	Weighted Statistic		Statistic
Panel v-Statistic	1.509*	0.207	Group rho-Statistic	-0.802
Panel rho-Statistic	-1.224	-1.476*	Group PP-Statistic	-5.436***
Panel PP-Statistic	-3.272***	-4.671***	Group ADF-Statistic	-6.437***
Panel ADF-Statistic	-3.319***	-4.739***		

Notes: Trend assumption include deterministic intercept and trend. Lag selection: Automatic based on SIC with a max lag of 3. Of the seven tests, the panel v-statistic is a one-sided test where large positive values reject the null hypothesis of no cointegration whereas large negative values for the remaining test statistics reject the null hypothesis of no cointegration.
*** Denote rejection of the null hypothesis of no cointegration at 1% significance level.
Source: Source: Own preparation using EViews 8

Table 6.5 represents the Kao (1999) panel cointegration results supports and confirms the cointegration between the variables for all our three models. The first part of the table denotes that there is cointegration between first-differenced values of GDP per capita as the depended variable, and renewable energy consumption, labor force, and gross fixed capital as independent variables with t-stat of (-2.679) and significance at 1%. The second part also reflects the cointegration between first-differenced values of GDP per capita, non- renewable energy consumption, labor force, and gross fixed capital as independent variables with t-stat of (-1.731) and significance at 5%. Finally, the third part of table 6.5 also confirms cointegration for total final energy consumption with t-stat of (-2.795) and significance at 51% respectively.

Table 6.5: Kao panel cointegration tests results

1.	**Model 1- REC**		**t-statistic**
		ADF	-2.679372***
2	**Model 2 - NREC**		
		ADF	-1.731254**
3	**Model 3 - TFEC**		
		ADF	-2.795187***

Notes: Denote rejection of the null hypothesis of no cointegration at ***, **, and *represent the significance at the 1%, 5%, and 10% level, (.).No deterministic trend.
Source: Source: Own preparation using EViews 8

Table 6.6 Reflects the estimation outcome of both models FMOLS and DOLS respectively.

Table 6.6: Panel FMOLS long-run estimates tests for BRICS countries, 1990–2014.

Model 1: GDP

Regressors	**FMOLS**	**DOLS**
REC	0.318	0.345
	(4.597)***	(3.441)***
K	0.439	0.442
	(18.319)***	(13.215)***
L	0.513	0.775855
	(4.309)***	(4.369)***
adj.R^2= 0.98		
Model 2: GDP		
NREC	-0.159	0.574
	(-2.524)**	(1.893)***
K	0.379	0.465
	(12.150)***	12.121)***
L	1.105	1.050
	(15.145)***	(5.184)***
adj.R^2= 0.98		
Model 3: GDP		
TFEC	0.242	0.245
	(3.401)***	(6.894)***
K	0.364	0.412
	(17.174)***	(13.169)***
L	0.812	0.801
	(19.872)***	(11.400)***
adj.R^2= 0.98		

Note: ***, **, and *represent the significance at the 1%, 5%, and 10% level, (.); t-Statistics are reported in parentheses respectively.

Source: Source: Own preparation using EViews 8.

However, the results show that all regressors are positive and statistically significance. The regression analysis of non-renewable energy consumption with economic growth, including labor force and fixed capital, the coefficient is negative in both estimated models (FMOLS and DOLS), thus a 1% increase in NREC will cause GDP to decrease by -0.159% in the FMOLS regression while a 1% increase in NREC will cause GDP to increase by 0.574% in the DOLS regression even though they are significant at 1% and 5% respectively. While for model 1; a 1% increase in REC will cause a GDP to increase by 0.318% in the FMOLS and

0.345% in the DOLS respectively. Finally, model 3 denotes that a 1% increase of TFEC will cause GDP to respond with an increase of 0.242% in the FMOLS and 0.245% the DOLS respectively. All variables are transformed into natural logarithms. Based on these results, we suggest that renewable energy consumption plays a bigger role in economic growth, thus BRICS governance and policymakers need to promote the generation and use of renewable energy to ensure sustainable economic development.

Table 6.7 represents the results of panel vector error correction model for the renewable energy consumption together with GDP per capita, labor force, and gross fixed capital respectively. With regards to eq.(8.1a), renewable energy consumption is positive and statistically significant at 10% also has an impact on the economic growth in the short-run. In terms of eq.(8.2a) GDP per capita is also positive and statistically significant at 10% for renewable energy consumption in the short-run. The error correction term represents the causality relationship in the long run and it is statistically significant with a relative speed of adjustment towards equilibrium in the long-run.

Table 6.7: Panel Granger- causality: [REC]

Dependent var.	**Independent variable**				
	Short-run causality				**Long-run**
	ΔLY	**ΔLREC**	**ΔLK**	**ΔLL**	**ECT**
(8.1a) **ΔLY** R^2 = 0.60	---	5.647*	9.448**	0.832	-0.432*** (-4.336)
(8.2a)**ΔLREC** R^2 = 0.44	6.229*	---	1.89	1.059	-0.021*** (3.549)
(8.3a)**ΔLk** R^2 = 0.56	3.774	0.437	---	0.823	-0.014*** (-2.929)
(8.4a)**ΔLl** R^2 = 0.48	0.797	0.437	0.489	---	0.007*** (4.073)

Notes: Partial F-statistics reported with respect to short-run changes in the independent variables. ECT represents the coefficient of the error correction term.

Source: Source: Own preparation using EViews 8.

Table 6.8 represent the results of the panel vector error correction model for the non-renewable energy consumption together with GDP per capita, labor force total, and gross fixed capital respectively. With regards to eq.(8.1b), non-renewable energy consumption is positive but statistically not significant thus it confirms that there is no impact on the economic growth in the short-run. In terms of eq.(8.2b) GDP per capita is also positive but statistically significant not significant thus it confirms that there is no impact on the renewable energy in the short-run. The error correction term represents the causality relationship in the long run and it is statistically significant with a relative speed of adjustment towards equilibrium for the long-run relationship. These findings confirm that there is a unidirectional causality in the long-run running from non-renewable energy consumption to GDP per capita without feedback.

Table 6.8: Panel Granger- causality: [NREC]

Dept. var.	**Independent variable**				
	Short-run causality				**Long-run**
	ΔLY	**ΔLNREC**	**ΔLK**	**ΔLL**	**ECT**
(8.1b) **ΔLY** R^2 = 0.58	---	2.105	12.142	1.788	-0.0031* (-1.)
(8.2b)**ΔLNREC** R^2 = 0.43	0.874	---	0.928	4.56	-0.009 (-0.267)
(8.3b)**ΔLk** R^2 = 0.52	4.989*	2.569	---	1.217	-0.001 (-1.557)
(8.4b)**ΔLl** R^2 = 0.49	1.294	3.292	0.481	---	-0.006*** (-4.054)

Notes: Partial F-statistics reported with respect to short-run changes in the independent variables. ECT represents the coefficient of the error correction term.

Source: Source: Own preparation using EViews 8.

Table 6.9 represent the results of the panel vector error correction model for the total final energy consumption together FTEC with GDP per capita, labor force, and gross fixed capital respectively. With regards to eq.(8.1c), total final energy consumption is positive and statistically significant at 5% respectively and also has an impact on the economic growth in the short-run. In terms of eq.(8.2c) GDP per capita is also positive and statistically significant at 1% for renewable energy consumption in the short-run. We also denote that gross fixed capital in the short-run is exogenous to both GDP per capita and total final energy consumption. The error correction term represents the causality relationship in the long run and it is statistically significant with a relative speed of adjustment towards equilibrium in the long-run. These findings confirm the bi-directional causality relationship in the short-run and long-run between TFEC and GDP per capita and are consistent with REC and GDP per capita of this study as represented by **table 6.9** respectively and thus, support feedback hypothesis parallel to Jebli, Youssef, & Ozturk (2016) for the role of renewable and non-renewable energy consumption and trade in OECD countries.

Table 6.9: Panel Granger- causality: [TFEC]

Dependent var.	**Independent variable**				
	Short-run causality				**Long-run**
	ΔLY	**ΔTFEC**	**ΔLK**	**ΔLL**	**ECT**
(8.1c)**ΔLY** $R^2 = 0.58$	---	4.222**	12.364***	0.261	-0.583*** (-5.392)
(8.2c)**ΔTFEC** $R^2 = 0.48$	6.004***	---	26.526***	1.704	-.019* (-1.779)
(8.3c)**ΔLk** $R^2 = 0.58$	2.706	15.135***	---	0.847	-0.004 (-0.784)
(8.4c)**ΔLl** $R^2 = 0.58$	1.442	1.126	0.595	---	0.014*** (5.197)

Notes: Partial F-statistics reported with respect to short-run changes in the independent variables. ECT represents the coefficient of the error correction term.

Source: Source: Own preparation using EViews 8.

7 Conclusion and policy implications

In this studied we examined quantitatively the impact of renewable energy, non-renewable energy and total final energy consumption to the economic conditions in a panel data framework of five BRICS countries for the period of 1990 to 2014. We applied the Pedroni (1999) and Kao (1999) for panel cointegration and causality relationship between the variables which accounts into multivariate models.

Will they implement expansive energy policies that will mean REC or NREC each causes economic growth? Or conservative energy policies must be implemented without any incompatible effect on economic growth? Does renewable energy consumption lead the way for the non-renewable energy consumption in both the short and long run? Is it optimal for the BRICS development bank to loan renewable projects in the short-run or long-run? What difference do we get estimating the total final energy consumption which is assumed to be the sum of both REC and NREC

Our empirical results firstly confirm that all the variables are stationary after first difference through tests LLC's test, Breitung t-stat and IPS-W statistics, IPS, and ADF-Fisher respectively and these findings are consistent with the findings by Ohlan (2016 Onishi et al. (2012).

Secondly, we denote the long-run relationship through the application of Pedroni (1999) and Kao (1999) panel cointegration tests among the variables. Thirdly our FMOLS and DOLS estimation results confirm that variables are significant. Thus they confirm that the variables of each estimation move together in the long-run and these findings are consistent with the findings by Nicholas Apergis & Payne (2009a, (2010b, (2012).

Lastly, the Granger causality results from support reflect the bidirectional causality relationship between renewable energy consumption and GDP per capita, also between total final energy consumption and GDP per capita. The error correction term represents the causality relationship in the long run and it is statistically significant with a relative speed of adjustment towards equilibrium for the long-run relationship. These findings confirm the bi-directional causality relationship in the short-run and long-run between REC and GDP per capita, thus, support feedback hypothesis. These results are parallel to the previous studies such as N Apergis & Payne (2010b) for 13 countries within Eurasia, Dogan (2016) analysis between renewable and non-renewable energy consumption and economic growth for Turkey, Sadorsky (2009) in research of Renewable energy consumption and income in emerging economies.

In contrasts, there is unidirectional causality relationship running from non-renewable energy consumption to GDP per capita thus, support growth hypothesis. These findings are consistent with those of Nicholas Apergis & Payne (2010a) also causality from energy consumption to economic growth, and Lin & Wesseh Jr. (2014) evidence of Granger causality from energy consumption to economic growth in South Africa. by confirming the unidirectional causality relationship only in the long-run from NREC to GDP per capita without feedback, thus, support the growth hypothesis. With respect to short-run causality, the results agree from those of Masih & Masih (1996) by supporting the neutral hypothesis.

BRICS negotiators and policymakers must promote renewable energy; however non-renewable findings suggest that expansive energy policies must be implemented.

Figure 7.1 represents the summary review from causality findings of the REC, NREC, and TFEC with the GDP per capita respectively.

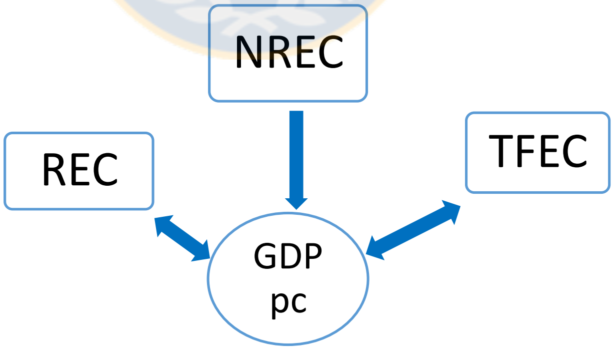

Figure 7.1: Causality relationship between GDP, REC, NREC, and TFEC.

Source: Own preparation

Findings from the renewable energy consumption and total final energy consumption suggests that BRICS group must implement effective expansive energy policies, thus encourages Brazilian Ministry of Mines and Energy (MME), the National Council for Energy

Policy (CNPE), Russian ministry of energy, Indian Ministry of New and Renewable Energy (MNRE), Chinese National Energy Agency (NEA), and South African National Energy Regulator of South Africa (NERSA) must strengthen formal tie and strategies on empowering the renewable energy sources.

The theoretical literature and findings of non-renewable energy consumption contradict with that of REC and TFEC thus encourages that the BRICS group countries to reinforce their conversation energy policies.

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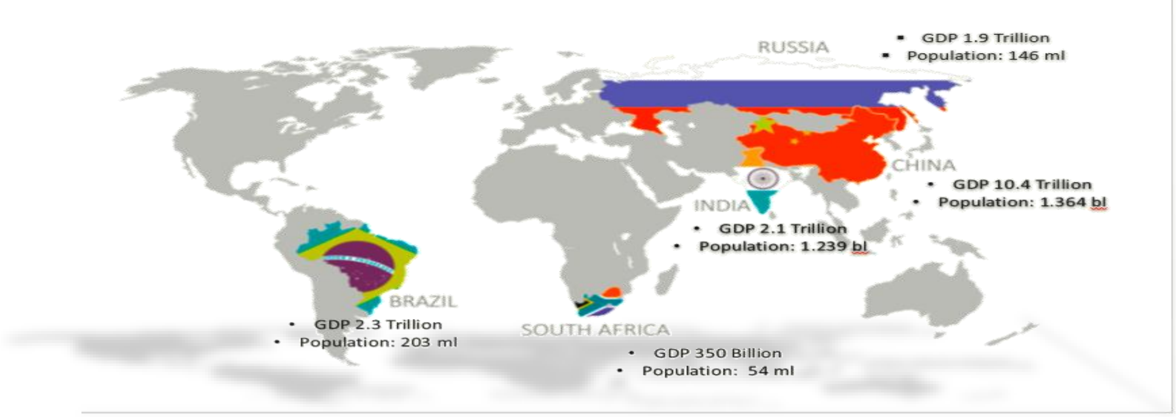
Appendix A: Population and Growth



Source: WorldBank, GDP, and population

Appendix B: Approximate conversion factors

Crude oil*	**To** tonnes (metric)	kilolitres	barrels	US gallons	tonnes/ year
From			**Multiply by**		
Tonnes (metric)	1	1,165	7,33	307,86	–
Kilolitres	0,8581	1	6,2898	264,17	–
Barrels	0,1364	0,159	1	42	–
US gallons	0,00325	0,0038	0,0238	1	–
Barrels/day	–	–	–	–	49,8

Source: British Petroleum

Units

1 metric tonne = 2204.62 lb.

1 kilolitre = 6.2898 barrels

1 kilolitre = 1 cubic metre

1 kilocalorie (kcal) = 4.187 kJ = 3.968 Btu

1 kilojoule (kJ) = 0.239 kcal = 0.948 Btu 1 British thermal unit (Btu) = 0.252 kcal = 1.055 kJ
1 kilowatt-hour (kWh) = 860 kcal = 3600 kJ = 3412 Btu