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Electricity Consumption and Economic Growth: A Panel Data Approach for Brazil, Russia, India, China and South Africa Countries

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ABSTRACT

This paper serves to investigate the causal relationship between electricity consumption and economic growth in the Brazil, Russia, India, China and South Africa (BRICS) countries during the period 1990–2014. Carbon dioxide emissions and urbanisation were included as additional variables to form a multivariate framework. The Kao panel co-integration and Johansen Fisher panel co-integration techniques are applied to analyse the co-integration relationship between the variables while the vector error correction model Granger-causality test is used to estimate the causality relationship among the variables. The study's results reveal that there is a long run relationship between the variables. The research outcome further detected a unidirectional causality flowing from economic growth to electricity consumption in the long run in BRICS countries. So in the light of determination of the study, the policy implication is that a significant transformation of low carbon technologies such as renewable energy should be implemented to curb the emissions and sustain economic growth and development.

Keywords: Energy Consumption, Economic Growth, Causality, Brazil, Russia, India, China and South Africa Countries
JEL Classifications: D04, Q47, Q42, Q01

1. INTRODUCTION

The importance of electricity consumption in developing countries like Brazil, Russia, India, China and South Africa (BRICS) has been viewed over the years as a significant factor contributing to economic growth and development. Digital technologies and modern economies are all dependent on a guaranteed supply of electricity. Electricity is referred to as a building block for economic growth (Khobai et al., 2017). It has a direct impact on livelihood and it is an infrastructural input in socio-economic development. Energy economists believe that electricity is the main driver of the factors of production and it is vital for manufacturing of goods into final products. This shows that when electricity is scarce, it imposes constraint to the growth of an economy.

The BRICS countries, BRICS are recognized as the most developed economies from the emerging countries. They have become an important force of the world economic stage. In recent years, the world energy consumption has risen rapidly driven by the slowing but still dynamic increase of energy consumption in BRICS (Enerdata, 2014). For instance China represented approximately 22% of the global energy consumption with Brazil lifting its world ranking to eight largest energy consumers. It was discovered that in 2013 BRICS validated their increasing dominant role in the new global energy landscape with a share of approximately 40% compared to the 20% it experienced in 2000 (Enerdata, 2014).

Despite being the largest energy consumers, the BRICS economies face challenges of greenhouse gas emissions. Most of the BRICS countries rely on coal to meet their rising demand for electricity. Coal is regarded as the main contributor to the world energy demand growth and it is one of the main sources of carbon dioxide emissions. In the BRICS group, Russia constitutes the largest contribution of fossil fuel on the energy matrix with 89.9%, followed by China which constitutes 86.8%. Brazil is the only one which stands out because it constitutes only 57.5% of fossil fuels in its energy mix. In terms of the carbon dioxide emitters, South Africa ranks 13th globally and the largest fossil fuel carbon dioxide emitter in the continent of Africa (Khobai and Le Roux, 2017). This raises questions as to whether this rapid increase in electricity consumption that causes high emissions of carbon dioxide in BRICS economies does enhance the level of growth in these countries. Therefore, this study employs the co-integration techniques and the Granger-causality test to examine the relationship between electricity consumption and economic growth in BRICS countries.

The remainder of the paper is organized as follows: Section 3 presents the review of the empirical literature. Section 4 discusses the methodology and data followed by section 4 which presents the analysis and interpretation of the study's results. Section 5 concludes the study and provides policy recommendations.

2. LITERATURE

Electricity demand is driven by the increasing modernisation of economies and industrialisation opportunities. It is regarded as a necessary factor for infrastructural development and the increasing standard of living (Masuduzzaman, 2013). Due to the importance of electricity consumption on economic growth and development, the causal relationship between energy consumption and economic growth has been investigated by many researchers over past decades (see for example: Acaravci and Ozturk, 2012; Shahbaz et al., 2014; Bouoiyour et al., 2014; Rafindadi and Ozturk, 2016; Sasana and Ghozali, 2017).

In Bangladesh, Ahmad and Islam (2011) and Mozumder and Marathe (2007) established that electricity consumption and economic growth are co-integrated. Ahmad and Islam (2011) and Mozumder and Marathe (2007) found bidirectional causality flowing between electricity consumption per capita to gross domestic product (GDP) per capita and economic growth. Masuduzzaman's (2013) research focused on Bangladesh and validated a unidirectional causality flowing from economic growth and electricity consumption to investment was found in the long term. The results imply that economic growth is driven by electricity consumption and investment in the long term.

Adebola and Shahbaz (2013) undertook a study for Angola for the period 1971-2009 and their findings suggested the existence of long term co-integration between electricity consumption, economic growth and urbanisation. The results further illustrated bidirectional causality between electricity consumption and economic growth. This implies that electricity is important for economic growth in Angola. Therefore, policies geared towards improvement of the electricity industry should be taken into consideration. Adebola et al. (2016) found that electricity consumption boots economic growth in Angola and established bidirectional causality flowing between economic growth and electricity consumption.

A study for Pakistan was done by Jamil and Ahmad (2010) who found a one-way causality flowing from real economic growth to electricity consumption. This study further showed that at the sectoral level private expenditure by the domestic sector increases electricity consumption, whereas in the manufacturing, commercial and agricultural sectors, output increases electricity consumption.

Shahbaz and Lean (2012) focused on Pakistan and their findings confirmed the existence of a positive long term relationship between electricity consumption and economic growth. The Granger-causality results showed a two-way causality between electricity consumption and economic growth. These results imply that implementation of the energy conservation policies are not necessary as it may lead to a decrease in electricity consumption and negatively affect economic growth.

Alam (2013) study focused on Pakistan and India and found different results for each of the two countries. Commencing with India, the results showed a unidirectional causality flowing from electricity consumption and foreign direct investments to economic growth and a unidirectional causality flowing from electricity power consumption and economic growth to foreign direct investments. The results for Pakistan established a one-way causality from economic growth and foreign direct investment to electricity consumption.

A study in Portugal was performed by Shahbaz et al. (2011). Their research found different results. Firstly, the long term causality established feedback hypothesis on all the variables except Granger-causality between electricity consumption and economic growth. In the short term all the variables proved bidirectional Granger-causality. A unidirectional Granger-causality flowing from economic growth to electricity consumption was also established.

Gurgal and Lach (2012) conducted a study for Poland and found different results for aggregate electricity consumption and disaggregated levels. Bidirectional causality was established between aggregate electricity consumption and GDP and, between employment and aggregate electricity consumption. At disaggregated levels, a neutral hypothesis was established between industrial electricity consumption and economic growth and a unidirectional causality flowing from industrial electricity consumption to GDP was observed

Danaraya and Hassan (2016) investigated the relationship between electricity consumption, manufacturing productivity and capital formation in Nigeria for the period between 1980 and 2013. The ARDL model results confirmed existence of a long run relationship between the variables. The Granger-causality results validated a feedback hypothesis between electricity consumption and manufacturing productivity.

Kouakou (2011) served to determine the Granger-causality relationship between electricity consumption per capita and economic growth in Cote d'Ivoire using their data for the period from 1971 to 2008. The findings portrayed a feedback hypothesis between electricity consumption per capita and GDP per capita. The study also detected a unidirectional causality flowing from electricity consumption to both GDP and Industry value added in the long term. Yuan et al. (2010) evaluated the causal relationship between economic growth and electricity consumption in China and validated a long term relationship between electricity consumption and economic growth in China. The estimations further found a one-way causality flowing from electricity consumption to economic growth.

Yoo and Kwak's (2010) study examined the relationship between electricity consumption and economic growth for Argentina, Brazil, Chile, Columbia, Ecuador, Peru and Venezuela and realised that the findings varied from one country to another. A growth hypothesis was established for Argentina, Brazil, Chile, Columbia and Ecuador. This implies that in these countries energy conservation policies are not necessary and that electricity policies should focus on measures aimed toward increasing electricity generation. A feedback hypothesis was found for Venezuela. This means that a change in electricity consumption directly affects economic growth. For Peru, the results showed no causality between electricity consumption and economic growth.

Chen et al. (2007) focused on the 10 newly industrialised and developing Asian countries and also found that the results differ across the countries and range from unidirectional causality or bidirectional causality to no causality. However, the results from the panel data frameworks portrayed two-way causality between electricity consumption and economic growth in the long run while in the short run, a unidirectional causality flowing from economic growth to electricity consumption was established. Narayan and Prasad's (2008) research studied the 30 OECD countries and established a unidirectional causality flowing from electricity consumption to economic growth for Australia, Iceland, Italy, the Slovak Republic, the Czech Republic, Korea, Portugal and the UK. A conservation hypothesis was established for the remaining 22 countries.

Apergis and Payne's (2011) study focused on 88 countries which were divided into four categories: high, upper middle, lower middle and lower income countries. The results from the panel co-integration test by Larsson et al. (2001) reported the existence of a long run relationship between the four variables mentioned. The panel vector error correction model (VECM) indicated a unidirectional causality flowing from electricity consumption to economic growth for low income country. It further showed that for lower middle income countries, a growth hypothesis was revealed in the short run while a feedback hypothesis was established in the long term. The high income and upper-middle income countries showed bidirectional causality flowing between electricity consumption and economic growth both in the long and short run. Economic growth does not only depend on electricity consumption, the free movement of goods and services within countries plays a pivotal role in economic growth.

Wen-Cheng (2016) studied 17 industries in Taiwan and the findings supported an existence of a long run relationship between the electricity consumption and economic growth. The results are such that a 1% increase in electricity consumption enhances economic growth by 1.72%. It was also established that economic growth and electricity consumption Granger-cause each other.

Cowan et al. (2014) investigated the causal relationship between electricity consumption, economic growth and carbon dioxide emissions for the BRICS countries. The results validated bidirectional causality between economic growth and electricity consumption for Russia and conservation hypothesis for South Africa. There was causality established flowing between electricity consumption and economic growth in China, India and Brazil.

As can be realised from the discussion of the literature review, the studies have primarily focused on electricity consumption and economic growth link on a bivariate framework. The problem of bivariate framework is the omitted variable bias. Our study fills in the gap by incorporating carbon dioxide emissions and urbanisation in the system to form a multivariate framework. It can also be observed that the results are sensitive to countries of choice, sample period and the methodology. It is therefore important to consider the relationship between these variables using the recent data. Our analysis is based on updated data and focuses on the BRICS countries which have been researched by few studies.

3. METHODOLOGY

3.1. Model Specification

The commonly used statistical model for investigating the relationship between electricity consumption and economic growth has been the standard linear functional specification. The standard linear functional specification for the relationship between electricity consumption and economic growth can be molded as follows:

$$EC_t = \alpha + \beta GDP_t + \varepsilon_t \tag{1}$$

Most studies have questioned the use of bivariate framework because of omitted variables bias between electricity consumption and economic growth (Cowan et al., 2014; Ahmad and Islam, 2011; and Mozumder and Marathe, 2007). For example Cowan et al. (2014) and Masuduzzaman (2013) incorporated carbon dioxide emission and investments variable, respectively, to form trivariate framework. Adebola et al. (2016) added exports, imports and urbanisation, while Shahbaz and Lean (2012) added labor and capital to form multivariate framework.

This study follows the methodology of a single multivariate framework by incorporating carbon dioxide emission and urbanisation as additional variables. In this regard, in examining the relationship between electricity consumption and economic growth, electricity consumption in this multivariate framework is taken as the dependent variable while GDP, carbon dioxide emissions and urbanisation are the explanatory variables. The model can therefore be presented as follows:

$$EC_t = f(GDP_t, CO2_t, UBN_t) \tag{2}$$

The standard log-linear functional specification of the aforementioned Eqn (1) can molded as follows:

$$EC_{i,t} = \alpha_1 + \alpha_{GDP} GDP_{i,t} + \alpha_{CO2} CO2_{i,t} + \alpha_{UBN} UBN_{i,t} + \varepsilon_t \tag{3}$$

LEC represents the natural log of electricity consumption per capita, LGDP denotes the natural log of real gross domestic product (using constant prices of 2015), LCO2 is the natural log of carbon dioxide emissions and LUBN represents natural log of urbanisation. Furthermore, α_1 and ε_t denote the constant and an error term, respectively.

3.2. Data Sources

The study utilises annual time-series data covering the period from 1990 to 2014 for electricity consumption, economic growth, carbon dioxide emissions and urbanisation. Different sources have been used to gather data of the mentioned variables. Real gross domestic product (using constant prices of 2010) was collected from the South African Reserve Bank. The data for carbon dioxide emissions, energy consumption and urbanisation were sourced from Word Development Indicators.

3.3. Methods of Data Analysis

3.3.1. Unit root tests

Prior to testing for co-integration, it is necessary to first ensure that all the variables have the same time series properties. Most importantly, they should be non-stationary at levels but be stationary when differenced once. The unit root examination is conducted using three unit root tests; namely, the Im, Pesaran and Shin W-stat (IPS), ADF-Fisher Chi-square and PP-Fisher Chi-square. In principal, the IPS can be used in connection with parametric unit-root test as long as the panel is balanced. The IPS test suggests that there exist individual unit root processes across the cross-sections.

In these tests the null hypothesis is that the series contains unit root, i.e. the variables is non-stationary and is tested against the alternative hypothesis that the series is stationary. If the computed test statistics is found to be less than the critical value at 5% level of significance, then we fail to reject the null hypothesis and this implies that the variable has a unit root.

3.3.2. Co-integration tests

When the variables are found to integrated of the same order, then the co-integration tests can be applied to examine the long run relationship between electricity consumption and economic growth. The principle of testing for co-integration is to determine whether two or more integrated variables deviate significantly from a certain relationship. Therefore, when variables are co-integrated, it means that they move together overtime such that the short run disturbances can be corrected in the long run.

This study uses two co-integration techniques; namely, Kao panel co-integration and Johansen Fisher Panel cointegration tests. The Kao panel co-integration uses both Dickey Fuller and Augmented Dickey-Fuller to test for panel co-integration. Kao (1999) considers cross-section specific intercepts and homogeneous coefficients during the first stage regressors. The following equation is used to start Kao panel co-integration i.e.,

$$Y_{it}=X_{it}\beta_{it}+Z_{it}\gamma_0+\varepsilon_{it} \tag{4}$$

Where Y and X are presumed to be non-stationary i.e.,

$$e^{it}=\rho e^{it}+vit \tag{5}$$

Where $e^{it}=(Y_{it}-X_{it}-Z_{it}^{\gamma})$

The following hypothesis is evaluated under the Kao panel co-integration test i.e.,

H_0:ρ=1 (No co-integration)

H_1:ρ<1 (Co-integration exists)

The Johansen-Fisher test statistics is calculated by summing over the P-values of the cross-sectional trace or maximum eigenvalue co-integration tests. The two tests differ in the formulation of the hypotheses. The maximum eigenvalue performs separate tests on each eigenvalue with an alternative hypothesis of exactly r+1 co-integrating vectors while the trace test is a one sided test with an alternative hypothesis of more r co-integrating vectors. Evidence of co-integration between electricity consumption and economic growth using Johansen-Fisher test statistic is obtained if the null hypothesis of none (r = 0) co-integration variables is rejected and the null of atmost 1 (r ≤ 1) co-integrating variables is accepted. This would imply that there is causality flowing from economic growth to electricity consumption. Therefore, this would confirm the existence of a long run relationship between these variables.

3.3.3. Granger-causality

The co-integration test only confirms that there is a long run and causal relationship among the variable but does not show the direction of causal relationship among the variables. To examine the causal relationship between electricity consumption, economic growth, carbon dioxide emissions and urbanisation in BRICS countries the Granger-causality based on the VECM approach is employed. This approach was developed by Engle and Granger (1987) and it incorporates the error correction term (ECT) to the VAR system as the additional variable. The advantage of the VECM is that it can estimate both long run and short causal relationships. The empirical equations of the VECM Granger-causality are presented as follows:

$$\begin{aligned}\Delta LEC_{it} &= \alpha_{1j}+\sum_{k=1}^{q}\alpha_{11ik}\Delta LEC_{it\text{-}k}+\sum_{k=1}^{q}\alpha_{12ik}\Delta LCO2_{it\text{-}k}\\ &\quad+\sum_{k=1}^{q}\alpha_{13ik}\Delta LGDP_{it\text{-}k}+\sum_{k-1}^{q}\alpha_{14ik}\Delta LUBN_{it\text{-}k}\\ &\quad+\psi_1 ECT_{t\text{-}1}+\varepsilon_{1it}\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta LCO2_{it} &= \alpha_{2j}+\sum_{k=1}^{q}\alpha_{21ik}\Delta LCO2_{it\text{-}k}+\sum_{k=1}^{q}\alpha_{22ik}\Delta LEC_{it\text{-}k}\\ &\quad+\sum_{k=1}^{q}\alpha_{23ik}\Delta LGDP_{it\text{-}k}+\sum_{k-1}^{q}\alpha_{24ik}\Delta LUBN_{it\text{-}k}\\ &\quad+\psi_2 ECT_{t\text{-}1}+\varepsilon_{2it}\end{aligned} \tag{7}$$

$$\begin{aligned}\Delta LGDP_{it} &= \alpha_{3j}+\sum_{k=1}^{q}\alpha_{31ik}\Delta LGDP_{it\text{-}k}+\sum_{k=1}^{q}\alpha_{32ik}\Delta LEC_{it\text{-}k}\\ &\quad+\sum_{k=1}^{q}\alpha_{33ik}\Delta LCO2_{it\text{-}k}+\sum_{k-1}^{q}\alpha_{34ik}\Delta LUBN_{it\text{-}k}\\ &\quad+\psi_3 ECT_{t\text{-}1}+\varepsilon_{3it}\end{aligned} \tag{8}$$

$$\Delta LUBN_{it} = \alpha_{4j} + \sum_{k=1}^{q} \alpha_{41ik} \Delta LUBN_{it-k} + \sum_{k=1}^{q} \alpha_{42ik} \Delta LEC_{it-k} + \sum_{k=1}^{q} \alpha_{43ik} \Delta LCO2_{it-k} + \sum_{k-1}^{q} \alpha_{44ik} \Delta LGDP_{it-k} + \psi_4 ECT_{t-1} + \varepsilon_{4it} \quad (9)$$

Where Δ is the first difference operator, k is the lag length set at one based on likelihood ratio tests and $\mathcal{E}$ represents serially uncorrelated random error term. ECT_{it-1} represents the co-integrating vectors. The presence of the long run causality flowing from the dependent variable(s) to the dependent variable can be established by examining the significance of the lagged ECT using a t-statistic on the coefficient ψ. The short run causality is examined by applying a joint test of the coefficients based on the F-test.

4. FINDINGS

4.1 Unit Root Tests

The findings of the Im, Pesaran and Shin W-stat, ADF-Fisher Chi-square and PP-Fisher Chi-square are illustrated in Table 1. The results posit that the variables electricity consumption, economic growth, carbon dioxide emission and urbanisation are not stationary at the level form but became stationary at the first difference level of significance (5%). This means that these variables are integrated of order one I(1) and contain a panel unit root. As a result, the study can test the long run relationship between the variables using the panel co-integration.

4.2. Co-integration

Since the results on stationarity confirmed that all the variables are integrated of the same order, the next step is to determine co-integration between the variables. The study applied the Kao panel co-integration and Johansen Fisher panel co-integration

The results in for Kao panel co-integration results are summarized in Table 2. The findings suggest that the ADF test statistics is significant. Therefore, the null hypothesis of no co-integration can be rejected at 1% level of significance. This implies that there is existence of a long run relationship between electricity consumption, economic growth, carbon dioxide emissions and urbanisation. These results are consistent with the findings of Shahbaz and Lean (2012) on Pakistan, Adebola et al. (2016) for Angola, and Danaraya and Hassan (2016) for Nigeria.

The Johansen Fisher panel co-integration test was also applied to confirm the results of co-integration between the variables and the results are presented in Table 3. Both the trace and the maximum eigenvalue tests fail to reject the null hypothesis of <3 co-integrating vectors at any level. This implies the variables are co-integrated.

4.3. Granger-causality

Having established the existence of a long run relationship among the variables, the study determines the direction of causality between electricity consumption, economic growth, carbon dioxide emission and urbanisation. The results are illustrated in Table 4. The results established a short run causality flowing from electricity consumption to economic growth. These results are consistent to the results by Yuan et al. (2010) for China and Alam (2013) for India.

The results further indicated that there is a long run causality running from economic growth, carbon dioxide and urbanisation to electricity consumption. This is on account that when electricity consumption was used as the dependent variable, the lagged error term was found to negative and significant. These results are consistent to Masuduzzaman's (2013) for Bangladesh.

When economic growth was used as the dependent variable, there was no causality found because the ECT is positive and not significant. The absence of a long run causality flowing from electricity consumption to economic growth means that environmentally friendly policies such as energy conservation, efficiency improvements measures and demand-side management

Table 1: Unit root tests

Variable	Level			
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
Im, Pesaran and Shin W-stat				
EC	2.60596	0.22385	−4.68993*	−4.59543
GDP	4.32261	−2.51773	−4.31654*	−3.15511*
CO2	1.66365	−0.66818	−5.45759*	−4.55284*
UBN	−2.10127	2.49001	1.87208**	0.71498**
ADF-Fisher Chi-square				
EC	5.30078	9.58930	40.2772*	37.0058*
GDP	1.88441	22.5177	37.6388*	27.4325*
CO2	6.09752	10.3105	46.6128*	36.7779*
UBN	20.0284	5.24586	2.12872**	5.20735**
PP-Fisher Chi-square				
EC	5.73266	6.89921	37.1526*	37.3719*
GDP	1.20251	13.5531	38.0162*	28.1101*
CO2	6.26869	3.82175	47.3655*	35.9243*
UBN	72.6193	0.32853	3.24808**	3.64060**

Source: Own Calculation. The optimal lag length was selected automatically using the Schwarz information criteria. The unit root tests were done with done with individual trends and intercept for each variable. *, ** represent significance at 1% and 5% levels. GDP: Gross domestic product

Table 2: Kao Panel co-integration results

Panel of BRICS countries	ADF test statistics	Probability value
	−3.5466	0.000

Source: Own calculation. H_o: There is no cointegration between the variables. H_1: There is a cointegration relationship between the variables

Table 3: Johansen Fisher Panel co-integration test results

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)				
Hypothesized No. of CE (s)	Fisher Stat.* (from trace test)	P	Fisher Stat.* (from max-eigen test)	P
None	76.70	0.0000	44.39	0.0000
At most 1	41.15	0.0000	20.17	0.0277
At most 2	31.73	0.0004	19.10	0.0390
At most 3	34.82	0.0001	34.82	0.0001

Table 4: Panel granger causality test results

Dependent variable	Types of causalities				
	Short run				Long run
	ΔEC	ΔGDP	ΔCO2	ΔUBN	Ect
ΔEC	-	4.414	0.903	0.334	−0.014*
ΔGDP	5.023**	-	1.307	2.319	0.002
ΔCO2	1.706	1.437	-	0.328	0.001
ΔUBN	3.588	3.132	0.289	-	5.840

Source: Own calculation. GDP: Gross domestic product

policies can be implemented in BRICS countries without adversely affecting economic growth.

5. CONCLUSION

This study examined the relationship between electricity consumption and economic growth in BRICS countries covering the period between 1990 and 2014. Other variables employed in the study include carbon dioxide emissions and urbanisation. The study employed the Kao panel co-integration and Johansen Fisher panel co-integration techniques to estimate the long run relationship between economic growth, electricity consumption, carbon dioxide emissions and urbanisation. To examine the causal relationship between the variables, Granger-causality based on the VECM was used.

The results from both the Kao panel co-integration and Johansen Fisher panel co-integration suggest that there is a long run linkage between electricity consumption, economic growth, carbon dioxide emissions and urbanisation in BRICS countries. Using VECM, we observed a unidirectional causality flowing from economic growth to electricity consumption in the long run. The study further showed that carbon dioxide emissions and urbanisation Granger-cause electricity consumption.

The implication of these results is that the reduction in electricity consumption will not have an adverse impact on economic growth. Therefore, the adoption of the policies to conserve electricity to avoid unnecessary loss in electricity can be implemented. It is also recommended that renewable energy should be used in the mix of energy to produce electricity in these countries to reduce carbon dioxide emissions.

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