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MODELING CAUSALITY BETWEEN ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH IN BIICS COUNTRIES

HELMI HAMDI[1]
RASHID SBIA[2]
ABDELAZIZ HAKIMI[3]
NABILA BOUKEF-JLASSI[4]

Abstract

This paper tests the causal relationship between per capita electricity consumption and gross domestic product (GDP) per capita for Brazil, India, Indonesia, China and South Africa for the period 1971–2009. To reach this goal, we use panel cointegration analysis and Granger causality tests. Our results reveal that electricity consumption and GDP are cointegrated and the granger causality tests indicate a long-run relationship between electricity consumption and GDP growth for all countries except for South Africa. The short-run estimations indicate that GDP granger cause electricity consumption but not the reverse; hence the existence of unidirectional short-run causality relationship between the two variables.

Keywords: Electricity consumption, Growth, BIICS, cointegration, Granger causality.

JEL Classifications: C32; Q43

1. Introduction

The BIICS[5] is a highly heterogeneous group of countries (Conway *et al.* 2010). These countries have witnessed a buoyant economic growth since 2000 and they became the preferred destination for international investors. China is the world's third largest country with 9,596,961 km^2 and most populous country with a population exceeding 1,347,350,000. Meanwhile, South Africa is the 25th largest country in the world with a population reaching 50,586,757. As well as being very different in land's and population's size, the BIICS are also different in size of their respective economy. According to the International Monetary Fund (2010) Brazil, India,

1 Corresponding author: CERGAM (4225) Aix-Marseille University, Tel: (973) 17547947. Fax: (973) 17532274. Email: helmi_aix@yahoo.fr

2 DULBEA, Free University of Brussels.

3 FSEG Jendouba. Tunisia

4 Laboratoire d'Economie d'Orléans. France

5 BIICS is an abbreviation for Brazil, India, Indonesia, China and South Africa.

Indonesia, China and South Africa are the 8th, 4th, 15th, 2nd and 25th world biggest economies respectively in term of Gross domestic product (PPP, US dollar).

Nevertheless, the BIICS share a number of common features (i.e.: impressive growth rate since decades, relatively low GDP per capita, high rate of informal employment, advanced stage of industrialization and poor quality of health services). Recently, a special attention is giving to the alarming level of pollution. According to the United States Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC) (2010) the BIICS are in the top 20 emitting countries by total fossil-fuel Co_2 emissions. China, India, South Africa, Indonesia and Brazil are ranked as 1st, 3rd, 12th, 14th and 15th most polluting countries.

Even though the abundance of literature and the importance of energy issues in Brazil, China, India, Indonesia, and South Africa, there is no article in our knowledge which analyzes the relationship between electricity consumption and economic growth in these countries. The BIICS is the largest bloc of developing countries and it becomes key player in the global economy. Hence, it is so worth to examine the consequences of the electricity consumption on the growth of these economies.

What has been explained previously is our main motivation to select BIICS countries and to test whether there is dynamic relationship between electricity consumption and gross domestic product within these countries. Our analysis has two dimensions: short-run and long-run. To reach this goal, we perform an econometric model based on panel cointegration technique and panel Granger causality. Our results reveal that electricity consumption and GDP are cointegrated and the granger causality tests indicate a long-run relationship between electricity consumption and GDP growth for all countries except for South Africa. The short-run estimations indicate that GDP granger cause electricity consumption but not the reverse; hence the existence of unidirectional short-run causality relationship the two variables.

The remainder of the paper is as follows: section 2 is literature review on the topic, in the section 3 we present the econometric methodology and data, section 4 analyzes the empirical results and section 5 concludes and draws some policy implication.

2. Literature Review

The relationship between energy consumption and economic growth nexus has received a great deal of attention throughout the modern history of energy economics. An enormous amount of studies has been made since the pioneering work of Kraft and Kraft, (1978).

However, despite the vast amount and heterogeneity of studies, the conclusion is not unanimous. In fact, the empirical evidence remains controversial and ambiguous to date, notably regarding the directions of the causal relationship between electricity consumption and economic growth. Chen and al. (2007) categorized these findings into four possible types and they explained the implications of each result.

First, the unidirectional causality running from electricity consumption to economic growth implies that restrictions on the use of electricity may adversely affects economic growth while increases in electricity may contribute to economic. This is hypothesis is known as electricity consumption-led growth hypothesis (or growth hypothesis). As example, Ho and Siu, (2007) has confirmed the growth hypothesis for Honk Kong for the period 1966–2002 using cointegration framework and vector error correction model. Similarly, Abosedra et al. (2009) suggested the growth hypothesis for Lebanon for the period 1995–2005 using Granger causality. Both Chandran et al. (2009) and Solarin (2011) used ARDL bounds testing to validate the growth hypothesis for Malaysia during 1970-2003 and for Botswana for the period 1980-2008 respectively.

Second, the unidirectional causality running from economic growth to electricity consumption would suggest that the policy of conserving electricity consumption may be implemented with little or no adverse effect on economic growth. The *conservation hypothesis* was valid for Australia in Narayan and Smyth, (2005) during the period ranging from 1966 to 1999 and for Taiwan in Hu and Lin, (2008) for the period 1982–2006 using Hansen–Seo threshold cointegration. Mozumder and Marathe, (2007) confirmed the conservation hypothesis for Bangladesh for the period 1971–1999 using VECM. Ciarreta and Zarraga, (2010) used Toda and Yamamoto, Granger causality–VAR and found that Spain could implement electricity conservation policy without hurting the economic growth. Similarly, Sami, (2011) found the same result for Japan using Auto Regressive Distributed Lag framework.

Third, a bi-directional causal relationship implies that electricity consumption and economic growth are jointly determined and affected at the same time. The *feedback hypothesis* has been revealed in some works as in Jumbe, (2004) for Malawi; Zachariadis and Pashouortidou, (2007) for Cyprus who used cointegration and VECM technique. Further, Tang, (2008) applied ECM based F-test and bound test and suggested that feedback hypothesis is present in the case of Malaysia. Moreover, Aktas and Yilmaz, (2008) and Lorde et al. (2010) found that electricity consumption and economic growth affect each other in the case of Turkey and Barbados. More recently, the study by Hamdi et al. (2014) on Bahrain show evidence of the feedback effect between electricity consumption and economic growth.

Finally, the absence of a causal relationship implies that electricity consumption is not correlated with economic growth, which means that neither conservative nor expansive policies in relation to electricity consumption have any effect on economic growth. Akpan and Akpan, (2012) confirmed *the neutrality hypothesis* in case of Nigeria for the period 1970- 2008 using a battery of test including ARDL bounds testing, Toda and Yomamoto and Variance Decomposition Analysis.

Since the eighties, scholars have dedicated their studies to examine the causal relationship between electricity consumption and economic growth nexus (Jumbe, 2004; Altinay and Karagol, 2005; Wolde-Rufael, 2005; Mazumder and Marathe 2007; Lean and Smyth 2010). In fact, electricity has been playing an important role in the development of human being’s life including means of transportation and communication. Rosenberg, (1998) inspected the history of electricity in the development of industrial sector.

Further, some studies have been carried out for a single country case study (Jumbe, 2004; Ghali and El-Sakka, 2004; Morimoto and Hope, 2004; Wolde-Rufael, 2004, Ouédraogo 2009). While some other for a panel of countries (Lee, 2005; Al-Iriani, 2006; Sari and Soytas, 2007; Lee and Chiang, 2008; Wolde-Rufael, 2006; Narayan and Smyth, 2008; Chontanawat et al., 2008; Pao and Tsai, 2010). This was motivated by significant policy implications for government in the design and implementation of its energy policy.

3. The Econometric Methodology and Data

Following literature of energy economics (Ghosh 2002, Jumbe 2004, Yoo 2006, Chen *et al.* 2007 etc.), the long-run relationship between electricity consumption and real GDP can be expressed as a linear logarithm form and specified as follows:

$$LELEC_{it} = \beta_{0i} + \beta_{1i} LGDP_{it} + \mu_{it} \quad \text{... (1)}$$

Where *i=1,…,N* for each country in the panel and t=1,…,T refers to the time period. $ELEC$ is the electricity consumption (measured by Kwt per capita) and GDP is the per capita real GDP (measured in constant 2000 US dollars). The variables of the equation (1) are expressed in natural logarithms and the parameters β_1 represent the long-run elasticity estimates of electricity consumption with respect to real per capita GDP.

The empirical study is based on annual data from 1971 to 2009 from the World Bank Development Indicators (WDI). Table 1 summarizes the main statistics associated with electricity consumption per capita and GDP per capita in BIICS countries.

Table 1. Statistical summary table

		Mean	**Std. Dev.**	**Observations**
	ELEC	1397.768	517.1234	39
Brazil	GDP	3447.405	487.5078	39
	ELEC	772.2026	680.7298	39
China	GDP	645.6275	577.2996	39
	ELEC	289.6640	150.2150	39
India	GDP	362.0218	155.3470	39
	ELEC	214.5607	188.1298	39
Indonesia	GDP	610.2542	249.7843	39
	ELEC	4026.199	741.3228	39
South Africa	GDP	3236.831	223.7656	39

The mean of per capita electricity consumption ranges from 214.56 Kwt in Indonesia to 4026.19 Kwt in South Africa. In addition, South Africa displays the most important variation in electricity consumption (in terms of the standard deviation) and India has the lowest electricity consumption per capita out of the BIICS countries. China occupies the second position in terms of electricity variation and consumption per capita. It is not surprising to see electricity consumption in South Africa and Brazil higher than China and India since the population in the later countries is much higher than the former countries.

In terms of real GDP per capita, South Africa has the highest per capita income (US$3236.83) followed by Brazil (US$3447.40) and the lowest income is India (US$362.02). The variations in real GDP per capita are quite large with the standard deviation of per capita income in China at 577.29 and for Brazil at 487.50.

The two graphs below illustrate the trajectory of the evolution of electricity consumption per capita and GDP per capita in BIICS since 1971.

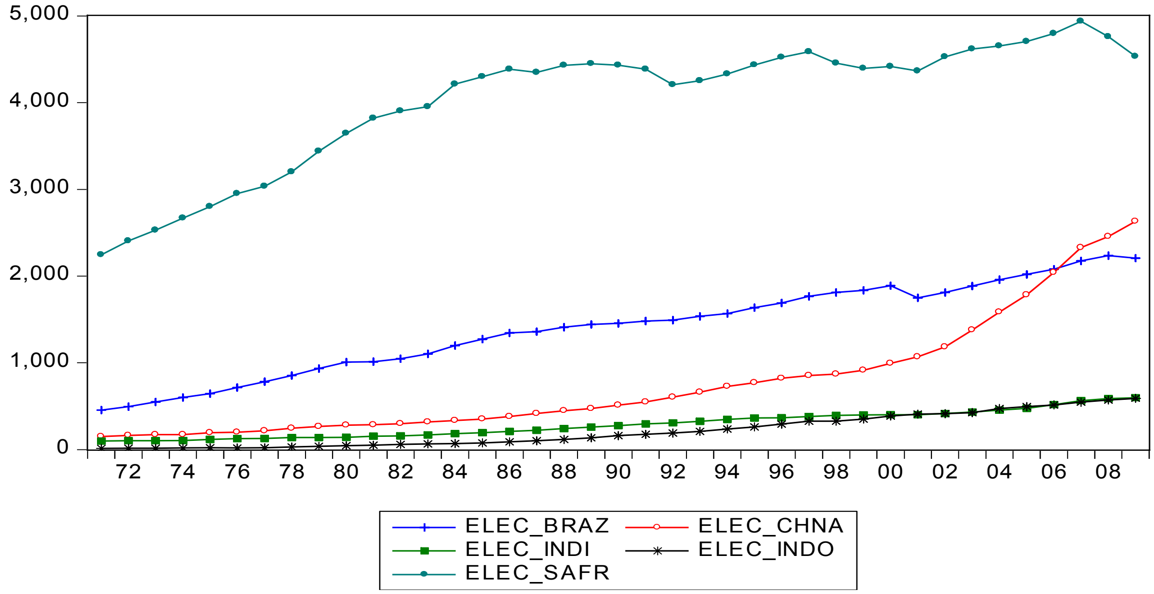

Figure 1. Evolution of per capita electricity consumption in BIICS

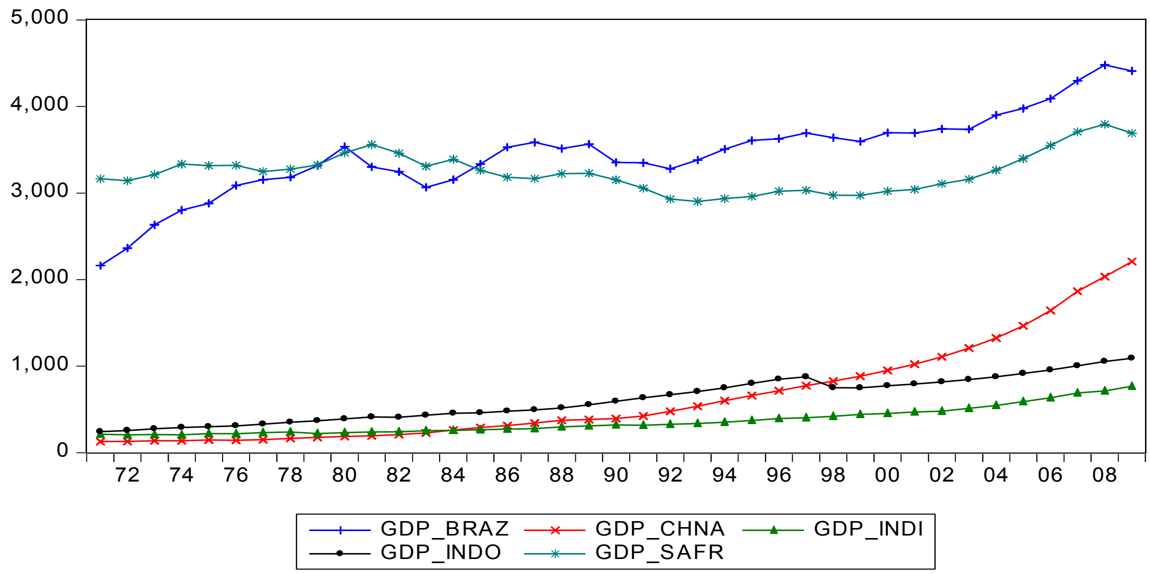

Figure 2. Evolution of per capita GDP in BIICS

Source: World Development Indicators (2012)

The aim of our empirical study is to examine whether there exist a dynamic relationship between electricity consumption and economic growth in the long-run and short-run as well for the case of BIICS countries. First, we start our analysis by testing for the stationarity of each variable using the Levin, Lin and Chu (LLC, 2002) test, the Im, Pesaran and Shin (IPS, 2003) test, the Breitung (2000) test and finally Hadri (2000) test. While the first three tests employ a null hypothesis of a unit root, the Hadri (2000) test uses a null of no unit root. After checking for stationarity of the variables, we proceed with Pedroni (1999, 2004) and Kao (1999) tests to identify the existence of panel cointegration relationship. In the following step, if we found that the two variables are integrated of order one and cointegrated, then we can conduct a panel vector error correction model (VECM) which is specified as follows:

$$\Delta LELECi_t = \beta_1 + \sum_{i=1}^{p} \beta_{1i} \Delta LELC_{t-i} + \sum_{i=1}^{q} \beta_{1i} \Delta LGDP_{t-i} + \lambda_1 ECT_{t-1} + \mu_{1t} \quad \text{... (2)}$$

$$\Delta LGDP_t = \beta_2 + \sum_{i=1}^{p} \beta_{2i} \Delta LGDP_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta LELEC_{t-i} + \lambda_2 ECT_{t-1} + \mu_{2t} \quad \text{... (3)}$$

Where ECT is expressed as follows:

$$ECT_t = LELEC_t - \beta_{0i} - \beta_{1i} LGDPi_t \quad \text{... (4)}$$

where *t=1..T,* denotes the time period.

4. Empirical Results

4.1. Panel unit roots and cointegration tests for BIICS

We use the following four different panel unit root tests : Levin and Chu (LLC, 2002), Im, Pesaran and Shin (IPS, 2003), Breitung (2000) and finally Hadri test (2000). Recent econometric literature reveals that Panel unit root tests are more powerful and reliable than individual unit root tests because the information in the time series is improved by that contained in the cross-section data (Ramirez 2006). The results are displayed in Table 2. The test statistics for the log levels of electricity consumption per capita and GDP per capita are statistically insignificant. When we apply the panel unit root tests to the first difference of the four variables, all four tests reject the joint null hypothesis for each variable at the 1 per cent level. Thus, from all of the tests, the panel unit roots tests indicate that each variable is integrated of order one.

Table2. Panel unit roots and cointegration tests for BIICS

	LLC		IPS		BREITUNG		HADRI (z-test)	
	level	**1st diff**	**level**	**1st diff,**	**level**	**1st diff,**	**level**	**1st diff,**
LELEC	-1.084	-5.873***	1.935	-5.367***	1.977	-5.364***	8.691***	1.750.***
LGDP	-0.535	-7.109***	0.189	-6.353***	0.225	-5.951***	8.821***	3.01***

*** indicates the rejection of the null hypothesis of non-stationarity (LLC, Breitung, IPS) or stationarity (Hadri) at the 1 percent level of significance

After checking the integration of our four variables at order one, I(1), the Pedroni, Kao and Fisher tests for balanced (BIICS) panel date are conducted. The results are displayed in Table 3 which reveals the rejections of the null of no cointegration for all tests at 5 % level of significance except the group rho-tests and panel v-test. Hence, we may confirm the fact that our model is panel cointegrated.

Table 3. Results of the balanced Panel Cointegration tests for BIICS countries

Pedroni Residual Cointegration Test	***Statistics***
Panel v-Statistic *Weighted Statistic*	-0.904793
Panel rho-Statistic *Weighted Statistic*	0.163542
Panel PP-Statistic *Weighted Statistic*	-1.731966**
Panel ADF-Statistic *Weighted Statistic*	-1.922745**
Group rho-Statistic	1.633826
Group PP-Statistic	-1.824137**
Group ADF-Statistic	-1.928638**
Kao Test.	
ADF	-1.310164* (0.0951)

Johansen Fisher Panel Cointegration Test

Null Hypo.	Max-Eigen.	Trace
None	44.90 (0.0000)***	31.97 (0.0004)***
At most 1	10.73 (0.5526)	25.83. (0.004)***

Note: The optimal lag lengths are selected using SBC. Figures in parenthesis are probability values.
** and *** Denotes the rejection of the null hypothesis at 5% and 10% level of significance respectively.

The Kao test also suggests panel cointegration at 10% level of significance. In addition, the Johansen Fisher test suggests the existence two cointegrating vectors at 1% level of significance. Overall, there is strong statistical evidence in favor of panel cointegration among electricity consumption per capita and GDP per capita in BIICS countries.

4.2. Panel Long-run and short-run

According to econometric theory initially developed by Granger (1969) and Engle and Granger (1987) the existence of cointegration signifies that there is at least one long-run equilibrium relationship among the variables. In this case, Granger causality exists among these variables in at least one way (Engle and Granger, 1987). The VECM is used to correct the disequilibrium in the cointegration relationship, as well as to test for long and short-run causality among cointegrated variables. The correction of the disequilibrium is done by the mean of the error correction term (ect).

The results of the long-run equilibrium relationship are presented in Table 4 below. It shows that the coefficient of LGDP for the whole panel is 0.789, which is positive and significant at the level of 1%. This means that an increase of 1% in GDP will increase electricity consumption per capita by 0.789% for BIICS. According to this result one may conclude that as soon as per capita income increases, households in BIICS countries would increase further their use of electricity. It is worth mentioning that, given the size of population and the large geographical areas in BIICS countries, access to electricity remains limited. However, it is well-known that the demand for electricity depends on the price for electricity as well as the price of alternative goods (substitution effects). Basically, the lower the price for energy, the higher the global consumption level will be (ceteris paribus). Therefore, an increase in income would increase the demand for electricity (essentially residential electricity demand).

At the individual country level, the coefficient is positive and significant at 5% level of significance for China and Indonesia and positive and significant at 1% level of significance for Brazil. In these countries, the demand for electricity is strongly associated with the level of income. In fact, when the income increases, households will buy electricity consuming equipment such as central air conditioning units, refrigerators, dishwasher and heaters, etc.

The coefficient of GDP is negative and significant at 5% level of significance for India but negative and non-significant for the South Africa. This means that a 1% increase in per capita income in the long run will decrease the per capita electricity consumption by 3.3% and 1.18% for India and South Africa respectively. This could be explained by the fact that in the long-run, households will move toward substitutes of traditional electricity goods that could save energy.[6] In this sense, electricity consumption is decreased, in a mixture of procedures, such as energy savings, profitable energy efficiency measures, or substitution of electricity for other energy sources that also decreases the carbon intensity of electricity production. For the case of India, it is worth recalling that policy makers have begun recognizing the need to resort to cleaner sources of energy, principally based on hydro power, solar and biomass energy. The government has undertaken numerous strategies to encourage the use of clean and green energy. In 2006 the government launched a plan to double the renewable energy capacity between 2012 and 2017 as part of efforts to raise efficiency of its energy use. The government has also settled a plan (India's 12th Five Year Plan: 2007-2012) that gave more importance of evolving a low carbon strategy for inclusive and sustainable growth. According to MNRE, India has installed more than 17.5 GW of renewable energy capacity, which is approximately 10% of India’s total installed capacity. Wind represents 11.8 GW, small hydro represents 2.8 GW, and the majority of the remainder is from biomass installations (Indian Renewable Energy Status Report, 2010). Nowadays, India’s citizens are becoming more environmentally aware. According the U.S department of commerce (2008 p.2) India could eventually be the largest renewable market in the world, given its abundance of renewable energy resources

Moving toward clean and green energy will improve the economic growth and improve the energy efficiency as well; this may explains why the coefficient of GDP is negatively associated with electricity consumption.

Table 4. Electricity long-run elasticities for BIICS

	Brazil	India	Indonesia	China	South Africa	Panel(BIICS)
Intercept	-8.817	24.852	-19.40	-15.522	15.744	1.003
LGDP	1.96 (7.355)***	-3.33 (3.955)**	3.98 (4.294)**	4.63(4.812)**	-1.18 (-0.60)	0.789 (7.923)***
Trend	-	-	-0.04(-1.29)	-0.31 (-4.07)**	0.13 (5.09)**	-

** and *** Denotes the rejection of the null hypothesis at 5% and 10% level of significance respectively

Turning now to short-run analysis, Table 5 illustrates the results in which DLELEC is the dependent variable. Given that the optimal lag length was two, the short-run results are also presented for two lags of each variable. Results of the panel BIICS show that GDP acts positively and significantly at the level of 10% to per capita electricity consumption. This means that a 1%

6 It is worth recalling that over 70 % of the electricity generated is from coal based power plants.

increase in per capita real GDP will increase electricity consumption by 0.17%. This shows that an improvement of GDP per capita encourages households in BIICS countries to use electricity in their everyday life. In this context, it is worth mentioning that during the past few years, BIICS countries have experienced buoyant economic growth and they have become among the best destination for doing business. In fact, as the number of foreign companies increased the wellbeing of BIICS citizens improved drastically and consequently the demand for electricity exploded.

At the individual country side, china is the only country with a negative coefficient of GDP while the coefficient is positive for Indonesia and South Africa and positive and significant at 10% level of significance for Brazil and India suggesting a 1% increase in per capita GDP will increase electricity consumption by 0.236% and 0.337% respectively. For the case of India, it is worth recalling that since the 80s the government has implemented several strategies to spread electricity to vast rural population (rural electrification). According to KPMG (2009) this plan has brought electricity to 200,000 villages for the first time. Further, generation capacity hit 150GW in 2006; a 40 percent increase on the 2000 figure, after reforms in 2003 initiated a much needed restructuring of the power sector. This plan was followed by a period of prosperity and buoyant economic growth. During the past two decades, India has become one of the preferred destinations for international investors and the regional hub of industry and manufactory. Today, India is the ninth largest economy in the world, driven by a real GDP growth of 8.7% in the last 5 years (Central Statistics Office, 2013). Consequently, economic condition and Indian's wellbeing improved drastically and the energy sector has witnessed a strong demand for cooling, ventilation, lighting and various kinds of office and network equipment.

It is also evident from Table 5 that the error correction term, although having the right sign, is statistically significant at the level of 10%. The coefficient of the error-correction term is -0.02748, suggesting that when per capita consumption is above or below its equilibrium level, it adjusts by almost 2.748% within the first year.

Table 5. Electricity short-run elasticities for BIICS

	Brazil	**India**	**Indonesia**	**China**	**South Africa**	**Panel (BIICS)**
ΔLGDP(1)	0.236*	0.337*	0.113	-0.284	0.019	0.177360*
ΔLGDP(2)	0.028	-	-	-0.004	-0.183	0.104566
Intercept	0.027**	0.024***	0.073***	0.058***	0.006***	0.03584***
ECT(-1)	-0.075*	-0.005 *	-0.07	0.039**	0.007	-0.02748***

*, ** and *** Denotes the rejection of the null hypothesis at 5%, 10% and 1% level of significance respectively

After examining long-and short-run dynamics, the next step is to investigate the direction of causality between per capita electricity conception and economic growth. The results of causality tests based on the VECM model are reported in Table 6 in which we have conducted three Granger causality tests: short-run causality, long-run causality and the joint short and long run.

Table 6. Results of causality tests based on VECM.

Variable	Short run (F-stats)		ECT	Joint short and long run (F-stats)	
	ΔLELEC	ΔLGDP	(t-stats)	ΔLELEC, ECT	ΔLGDP, ECT
ΔLELEC	-	3.626***	-0.27***	-	12.320***
ΔLGDP	0.56	-	0.002	0.378	-

*** Denotes the rejection of the null hypothesis at 1% level of significance.

The F-statistics for the short-run dynamics reveals a unidirectional causality running from GDP per capita to per capita electricity consumption but not the reverse. This shows that an increase in income would inevitably increases the use of electricity in BIICS countries. As we have discussed previously, the boom that have witnessed these countries during the past decade have improved their economic conditions as well as the wellbeing of their citizens. Income has increased significantly and the demand for basic energy exploded. This conclusion supports the findings reported in Table 5 in which GDP per capita is significant at 10% the level of significance.

Table 6 also shows that the coefficient of the error correction term is significant in the electricity per capita equation. This confirm that deviation from the long-run equilibrium is corrected by per capita electricity consumption while GDP per capita appears to be weakly exogenous. This reveals the fact that any changes in GDP per capita that disturb long-run equilibrium are corrected by counter-balancing changes in the per capita electricity consumption.

Turning now to the right side of table 6, the joint Wald F-statistics results indicate in the electricity consumption equation, error correction term and GDP per capita are jointly significant at a level of 1%. Hence, there is a Granger causality running from GDP to electricity consumption. This result confirms the strong linkage between the level of income and the electricity demand in BIICS countries.

5. Concluding Remarks

This study aims at analyzing the dynamic relationship between electricity consumption and real GDP for a panel of BIICS countries over the period ranging from 1971 to 2009 and to obtain the policy implications of these results. First set of tests show the existence of a cointegration relationship and results of the long-run elasticities demonstrate that GDP per capita is positively and significantly linked to per capita electricity consumption for the whole sample. The short-run dynamics suggests unidirectional causality from per capita GDP to per capita electricity but not the reverse. This means that an increase in per capita income would increase the demand for electricity and not the reverse for the short term. For the panel as a whole, BIICS countries appear to be not energy-dependent economies. A high level of economic growth leads to high level of energy demand but the reverse is not approved in this study.

An increase in per capita income would encourage households to use more energy for example some electricity services for cooking, cooling, heating and lighting or simply would facilitates access to basic electricity services i.e., lighting. However, access to electricity is still limited for some BRIICS countries. For example the electrification rate in Indonesia is 64.5%, 75.0% in India and 75% in South Africa which is still modest compared to others emerging countries (WEO 2011). Therefore, clean and green energy could play an important role in extending basic electricity to vast rural population and to meet future demand for electricity. The huge geographical size of BIICS countries gives considerable opportunities in terms of hydro, biomass and solar energy. The widespread use of energy, notably electricity, in all these countries would also create an immense opportunity for further economic growth as they could be an attraction for multinational companies and international investors.

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