Modeling causality between Electricity consumption and Economic Growth in BIICS Countries

Helmi HAMDI and Rashid SBIA

2012

Modeling causality between Electricity consumption and Economic Growth in BIICS Countries

Helmi HAMDI*, Aix-Marseille University CERGAM (4525), France
Corresponding author: helmi_aix@yahoo.fr, Tel +973.36003466
Rashid SBIA. DULBEA, Solvay Brussels School of Economics and Management, Belgium

Abstract

This paper tests the causal relationship between electricity consumption per capita 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 the two variables.

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

JEL codes: C32; Q43

1. Introduction

The relationship between energy consumption and economic growth nexus has received a great deal of attention throughout the modern history of energy economics. Since the eighties, some authors have focused their researches on the consequences of carbon dioxide emission on output (Yu and Choi, 1985; Ghali and El-Sakka, 2004; Mahadeven and Asafu-Adjaye, 2007; Akinlo, 2008, Payne 2010), whereas some others 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 addition, 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, 2008; 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.

Despite of the 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. 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. Third, a bi-directional causal relationship implies that electricity consumption and economic growth are jointly determined and affected at the same time. 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.

Despite the abundance of literature and the importance of energy in Brazil, China, India, Indonesia, and South Africa (BIICS henceforth), 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.

Broadly, the BIICS 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. While 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, 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) (2008) 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, 13th, 15th and 17th most polluting countries.

What has been explained previously is our main motivation to select BIICS countries 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. The reminder of the paper is as follows: in section 2 we present the econometric methodology and data, section 3 analyzes the empirical results and section 4 concludes.

2. The Econometric methodology and data

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 (Kwt) and GDP per capita (constant 2000 USS) in BIICS countries.

Table 1: Statistical summary table

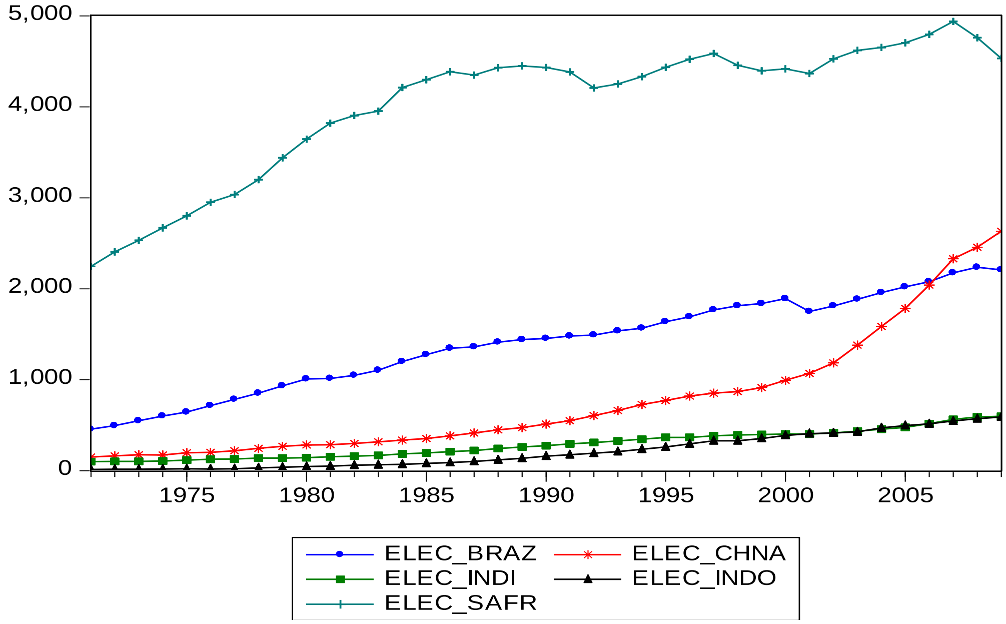
		Mean	Std. Dev.	Observations
Brazil	ELEC	1397.768	517.1234	39
	GDP	3447.405	487.5078	39
China	ELEC	772.2026	680.7298	39
	GDP	645.6275	577.2996	39
India	ELEC	289.6640	150.2150	39
	GDP	362.0218	155.3470	39
Indonesia	ELEC	214.5607	188.1298	39
	GDP	610.2542	249.7843	39
South Africa	ELEC	4026.199	741.3228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

The mean of electricity consumption per capita ranges from 214.56 Kwt in Indonesia to 4026.19 Kwt in South Africa. In addition, South Africa reveals the most variation in electricity consumption (defined by the standard deviation) and India the least variation with 741.32 and 150.21 respectively. China occupies the second position in terms of electricity variation and consumption per capita.

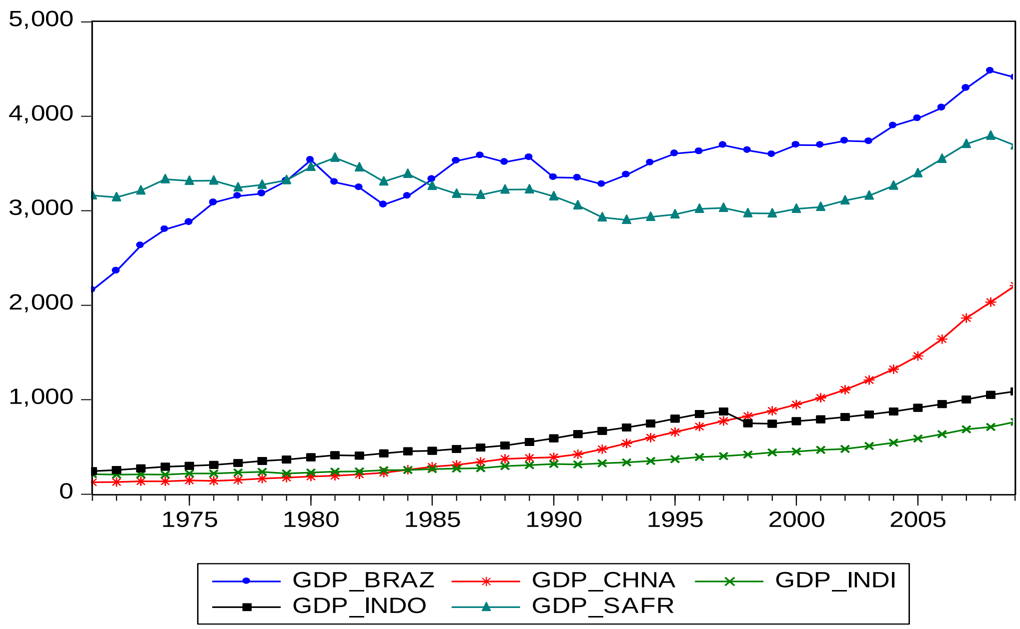
In terms of real GDP per capita, the highest mean per capita income levels is in South Africa (3236.83) followed by Brazil (3447.40) and the lowest income is India (362.02). The variations in real GDP per capita are quite large with the standard deviation of per capita income in China at 577.29 and for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

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

Graph1. Evolution of Eclectricity consumption per capita in BIICS since 1971



Graph 2. Evolution of GDP per capita in BIICS since 1971



Our empirical investigation has two dimensions. The first is to examine the long-run relationship between carbon electricity consumption and real GDP, while the second is to examine the short-run dynamic causal relationship between the variables. The basic testing procedure requires three steps. The first step is to test whether the variables contain a panel unit root to confirm the stationarity of each variable (Engle and Granger, 1987). This is done by using the Levin and Chu test, (LLC, 2002), the Im et al. test (Im, Pesaran and Shin (IPS, 2003)), the Augmented Dickey–Fuller test (F-ADF) (Maddala and Wu, 1999; Choi, 2001) and finally Breitung (2000) test. The second step is to test whether there is a long-run cointegrating relationship between the variables. This is done by the use of the Johansen-Fisher (Maddala and Wu, 1999; Kao, 1999; Pedroni, 1999, 2004) methods. Finally, the last step, if all variables are I(1) (integrated of order one) and cointegrated (Masih and Masih, 1996), short-run elasticities can be computed using the vector error correction model (VECM) method suggested by Engle and Granger (1987). In this case, an error correction mechanism exists by which changes in the dependent variables are modeled as a function of the level of the disequilibrium in the cointegrating relationship, captured by the error-correction term (ECT), as well as changes in the other explanatory variables to capture all short-term relations among variables (Pao and Tsai, 2010).

3. Empirical results

3.1. Panel unit roots and cointegration tests for BIICS

We use the panel unit root tests as proposed by Levin and Chu (LLC, 2002), Im, Pesaran and Shin (IPS, 2003), the Augmented Dickey–Fuller (F-ADF) and finally Breitung (2000). 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**		**F-ADF**		**Breitung**		**Order of Integration**
	level	1st diff	level	1st diff,	level	1st diff,	level	1st diff,	
LELECpc	-1.084	-5.873***	1.935	-5.367***	1.977	-5.364***	1.768	-5.252***	I(1)
LGDPpc	-0.535	-7.109***	0.189	-6.353***	0.225	-5.951***	0.375	-6.601***	I(1)

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 used.

Pedroni (1999, 2004) suggests two sets of tests for cointegration: the between and the within dimensions. The within approach includes four statistics panel v-statistic, panel r-statistic, panel PP-statistic, and panel ADF-statistic. These statistics pool the autoregressive coefficients across different countries for the unit root tests on the estimated residuals taking into account common time factors and heterogeneity across countries. The between approach includes three statistics: group r-statistic, group PP-statistic, and group ADF-statistic. These statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals for each country. All seven tests are distributed asymptotically as standard normal.

The test results of Pedroni displayed in table 3 reveal 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. However, according to Pedroni (2004), the two Pedroni test statistics which do not reject the null hypothesis may have a very low power in the case of small time dimension. This fact is also observed by Al-Iriani (2006) and Pao and Tsai (2010). Therefore, one may conclude that our model is in fact 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
r=o	44.90 (0.0000)***	31.97 (0.0004)***
r<1	10.73 (0.5526)	25.83. (0.004)***

Note: The optimal lag lengths are selected using SBC. Figures in parenthesis are probability values.
Trace test and Max-eigenvalue test indicate 2cointegrating vector at the 0.01 level
*** Denotes the rejection of the null hypothesis at 1%level of significance

The Kao test also suggests panel cointegration at 5% level of significance. In addition, the Johansen Fisher test suggests the existence two cointegrating vectors at 1% 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.

3.2. Panel Long run and short run

Generally speaking, 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).

To test for panel causality, a panel-based VECM is specified as follows:

$$\Delta LELECpc_t = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta LELCpc_{t-i} + \sum_{i=1}^{q} \beta_{1i} \Delta LGDPpc_{t-i} + \lambda_1 ECT_{t-1} + \mu_{1t} \qquad (1)$$

$$\Delta LGDPpc_t = \alpha_2 + \sum_{i=1}^{p} \beta_{2i} \Delta LGDPpc_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta LELECpc_{t-i} + \lambda_2 ECT_{t-1} + \mu_{2t} \qquad (2)$$

Where ECT is expressed as follows:

$$ECT_t = LELECpc_t - \beta_0 - \beta_1 LGDPpc_t \qquad (3)$$

Where $t=1..T$, denotes the time period

The results of the long-run equilibrium relationship are presented in table 4 below. It shows that the coefficient of LGDPpc 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 GDPpc will increase electricity consumption per capita by 0.789% for BIICS.

At the individual country level, the coefficient is positive and significant at the level of 5% for China and Indonesia; negative and significant at the level of 5% for India, negative and non significant for and South Africa and finally positive and significant at the level of 1% for Brazil. This means that an increase in GDP per capita will increase the consumption of electricity per capita in china, Indonesia and Brazil in the long-run while, an increase in GDP will decrease the electricity consumption per capita in India and South Africa.

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
LGDPpc	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)**	-

Table 5 illustrates the results in which DLELECpc 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 show that GDP act positively and significantly at the level of 10% to electricity consumption.

At the individual country level, the coefficient is positive and significant at the level of 10% for Brazil and India; positive and non significant for Indonesia and South Africa and finally negative and non significant in China.

It is also evident from Table 5 that the error correction term, although having the right sign, is statistically significant at the level of 1%. 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)
Intercept	0.027**	0.024***	0.073***	0.058***	0.006***	0.03584***
ΔLELECpc(-1)	0.335*	0.180	0.202	0.345*	0.432*	0.291605***
ΔLELECpc (-2)	0.009	-	-	0.165	0.119	-0.104063
ΔLGDPpc (-1)	-0.236*	0.337*	0.113	-0.284	0.019	0.177360*
ΔLGDPpc (-2)	0.028	-	-	-0.004	-0.183	0.104566
ECT(-1)	-0.075*	-0.005 *	-0.07	0.039**	0.007	-0.02748***

The existence of a panel long-run cointegration relationship among emissions, electricity consumption, and GDP suggests that there must be Granger causality in at least one direction. Thus, the next concern is to inspect the direction of causality amongst these variables. The results of causality tests based on the VEC model are reported in Table 6. The table has three major blocks illustrating the short-run effects, long-run effects represented by the error correction coefficients, and the joint short-run and long run effects, respectively.

Table 6. Results of causality tests based on VECM.

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

The F-statistics for the short-run dynamics reveals a unidirectional causality between GDP per capita to ELEC per capita but not the reverse. This results support our findings reported in Table 5 in which GDP per capita is significant at the level of 10%. Regarding error correction results, the coefficient is found to be significant in the electricity per capita equation. This confirm that deviation from the long-run equilibrium is only 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 indicate whenever there is a shock, GDP would make short-run adjustments to reestablish long run equilibrium.

4. 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 from 1970 to 2009 and to obtain policy implications of the 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 GDP per capita to electricity per capita but not the reverse. This means that an increase in GDP contribute to the increase in energy consumption and not the reverse for the short term. An increase in GDP per capita will encourage households to consume more electricity by buying for example some electricity services for cooking and for improving the living standard. However, access of 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), thus an increase in

GDP per capita will increase the electrification rate in these countries. In this case, any policy conserving electricity consumption may be implemented without affecting economic growth (or with a little consequence) of BIICS.

For a 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. The evidence also suggests that both electricity consumption and GDP response to deviation in long-run equilibrium in period t-1, and whenever a shock occurs in the system, both emissions and energy consumption bear the burden of the short-term adjustment to restore long term equilibrium (Tsai and Pao). Thus, energy consumption infrastructure shortage could not restrain the economic growth. Hence, the best environmental policy regarding energy conservation and economic growth is to increase macroeconomic activities and investment which will in turn increase the electricity consumption and improve the living standard of these countries. Moreover, since BIICS countries are not energy-dependent developing economies, any policy electricity conserving policy may not cause any damage to their economies.

References

Altinay, G., Karagol, E., 2005. Electricity Consumption and Economic Growth: Evidence from Turkey. Energy Economics, 27, 849-856.

Asafu-Adjaye, J., 2000. The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries. Energy Economics, 22, 615-625.

Breitung, J. (2000): The Local Power of Some Unit Root Tests for Panel Data, in: B. Baltagi (ed.), Nonstationary Panels, Panel Cointegration, and Dynamic Panels, Advances in Econometrics, Vol. 15, JAI: Amsterdam, 161-178.

Chang, J., Wong, J. F. 2001. Poverty, energy and economic growth in Singapore. Working Paper, Department of Economics, National University of Singapore.

Conway, P., Dougherty, S., Radziwill, A., 2010. *Going for Growth* in Brazil, China, India, Indonesia and South Africa. *OECD Economics Department Working Papers*.

Engle, R., Granger, C. W. J., 1987. Cointegration and Error- Correction Representation, Estimation and Testing. Econometrica, 55, 251-276.

Granger, C. W. J. (1981): "Some Properties of Time Series Data and Their Use in Econometric Model Specification", *Journal of Econometrics*, Vol. 16, pp. 121-30

Johansen, S. (1988). ''Statistical Analysis of Cointegrating Vectors'', *Journal of Economic Dynamics and Control*, Vol. 12, 231-254.

Jumbe, C. B. L., 2004. Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi. Energy Economics, 26, 61-68.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data, *Journal of Econometrics,* 90,1-44.

Kraft, J., Kraft, A., 1978. On the Relationship between Energy and GNP. Journal of Energy and Development, 3, 401-403.

Lean, H. H., Smyth, R., 2010. Co2 Emission, Electricity Consumption and Output in ASEAN. Applied Energy, 87, 1858-1864.

Lee, C. C., 2005. Energy Consumption and GDP in Developing Countries: A Cointegrated Panel Analysis. Energy Economics, 27, 415-427.

Levin, A., F. Lin, and C. Chu (2002): Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties, *Journal of Econometrics*, 108, 1-24.

Masih, A., Masih, R., 1996. Energy Consumption, Real Income and Temporal Causality: Results from a Multi-Country Study Based on Cointegration and Error Correction Modeling Techniques. Energy Economics, 18, 165-183.

Masih, A., Masih, R., 2000. Are Asian Stock Market Fluctuations Due Mainly to Intra-Regional Contagion Effects? Evidence Based on Asian Emerging Stock Markets. Pacific Basin Finance Journal, 7, 251-282.

Mazumder, P., Marathe, A., 2007. Causality Relationship between Electricity Consumption and GDP in Bangladesh. Energy Policy, 35, 395-402

Nanthakumar, L., Subramaniam, T., 2010. Dynamic Cointegration Link between Energy Consumption and Economic Performance: Empirical Evidence from Malaysia. International Journal of Trade, Economics and Finance, Vol.1, No.3.

Narayan, P. K., 2005. The Saving and Investment Nexus China: Evidence from Cointegration Test. Applied Economics, 37, 1979-1990.

Ouédraogo I (2009) Electricity consumption and economic growth in Burkina Faso: A cointegration analysis. Energy Economics Volume 32, Issue 3, May 2010, Pages 524–531

Pao H T Tsai C M (2010), CO2 emissions ,energy consumption and economic growth in BRIC countries. Energy Policy 38 (2010) 7850–7860.

Payne J E (2010), A survey of the Electricity Growth Nexus, Applied Energy, Volume 87, Issue 3, March 2010 pp 723-731.

Pedroni, P., (2004). Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with application to the PPP hypothesis, *Econometric Theory*, 20(3), 597-625.

Pesaran, M. H., Shin, Y., Smith, R. J., 2001. Bounds Testing Approaches to the Analysis of Level Relationships. Journal of Applied Econometrics, 16, 289-326.

Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regression. Biometrika, 75, 335–346.

Stern, D. I., 2000. A Multivariate Cointegration Analysis of the Role of Energy in the US Macro Economy. Energy Economics, 22, 267-283.

Wolde-Rufael, Y., 2005. Electricity Consumption and Economic Growth: A Time Series Experience for 17 African Countries. Energy Policy, 34, 1106-1114.

World Bank, 2009. World Development Indicators 2009. Washington: United States.

Yu, E. S., Choi, J. Y., 1985. The Causal Relationship between Energy and GNP: An International Comparison. Journal of Energy and Development, 10, 249-272.