Explaining the relationship between energy consumption and economic growth in a dynamic panel model: Are the BRICs countries different?

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***Abstract*—** *The aim of this paper is to explore the energy consumption-economic growth nexus for four emerging countries (Brazil, Russia, India and China – the BRIC countries) over the period 1989-2014. By applying a set of recent panel data models, we show that increases in real per capita GDP have a positive and statistically significant effect on per capita energy consumption (and vice-versa). In the long term, a 1% increase in real per capita GDP raises the energy consumption per capita by about 0.56-0.67% while a 1% increase in per capita energy use increases the real per capita GDP by about 0,87-1.69%. Thus, the impact of real GDP on energy consumption is less important than vice versa.*

Keywords*— *the BRICs countries, the energy-growth nexus, panel cointegration methods.

I. INTRODUCTION

The long-term sustainability of global energy markets faces major challenges today due to the current demographic, economic, social and technological global trends. One of its defining features over the past ten years is the dynamic raise of energy needs and economic growth in the emerging market economies compared to OECD countries while the predicted global energy supply will be stable and dominated by fossil fuels to 2030. According to the 2014 annual report of Enerdata, the world energy consumption has raised slightly in 2013 (+1.9%, compared to 1.8% in 2012 and +1.6% in 2011). This increase was primarily due to the dynamic rise of energy needs in four emerging economies, the so-called BRIC's economies of Brazil, Russia, India and China (+3.5 in 2013, +4.4% in 2012 and 5.6%/year average between 2000 and 2011) and to the return to growing energy demand in the USA (+2.5%) after two successive reductions in the previous years (2.6% in 2012 and 1.1% in 2011). Therefore, understanding the behavior of energy use in the emerging markets, particularly in the BRICs, is crucial for achieving the goals of energy efficiency, and implicitly the long-term sustainability of global energy system.

The relationship between energy consumption and economic growth was actively analyzed in the energy literature since the seminal Kraft and Kraft (1978) paper for both developing countries (see for example, Akinlo, 2008; Chen and al., 2007; Yoo, 2006 and Lee, 2005) and developed countries (Apergis and Payne, 2009, 2010a, 2011b, 2010d; Coers and Sanders, 2013, Salim et al., 2014 among others) given the lack of consensus on the direction of causality between these two variables, regardless of the nature of empirical studies (time series or panel data), the length of the periods or the country samples.

Given the importance of BRIC's economies in the emerging markets growth over the past decade, the empirical literature (e.g., Pao and Sai, 2010; Arseneau, 2011) has made some paces in modeling this relationship. However, it still remains a very open field of research.

Ozturk et al. (2010) and Apergis and Payne (2011) synthesize the approaches found in the energy economics literature in four major hypotheses: "the growth hypothesis" (meaning the unidirectional causality from energy consumption to economic growth), "the conservation hypothesis" (implying the unidirectional causality from growth to energy use), "the neutrality hypothesis" (meaning that there is no a linkage between these two variables) and "the feedback hypothesis" (referring to a bi-directional causality between these dimensions). From the point of view of policy implications, the growth hypothesis means that a decline in energy use negatively influences economic growth or that policies aiming to limit energy consumption stimulate growth. In opposition, the conservation hypothesis and neutrality hypothesis imply that adjustments in energy policies do not impact economic growth.

The purpose of this paper is to explore this debated relationship for BRIC's countries over the period 1989-2014. Our contribution to the existing empirical literature is fourfold. Firstly, very little studies have been done on modeling this relationship for this region (e.g., Pao and Sai, 2010; Arseneau, 2011). Secondly, at our best knowledge, no panel study has been done to evaluate this relationship for the BRIC economies on a recent time-span (26 years) covering the recent global financial crisis period. Thirdly, some of these four regions are of strategic importance for EU energy supply security. It is well known that Russia with the Middle East, North Africa, and Norway are now the largest EU's suppliers. Fourthly, the Chinese's energy consumption recorded the highest raise among the G20 countries in 2013 (+4.7% - less than its previous trends according to Enerdata, 2014) which directly influences the world's trend as China represented 22% of the global energy use in 2013 (compared to 12% in 2000). Overall, the BRICs economies constitute the primary tool for global energy consumption growth. Fifthly, the paper employs recent panel data models like: Kao and Chiang (2000) - the group-means fully modified ordinary least squares (FMOLS) estimator that considers a semi-parametric correction to the ordinary least squares (OLS) estimator, a parametric dynamic OLS (DOLS). Finally, the results may provide further support for the economic approaches exploring the relationship between energy use and economic activity. Results show that raises in real per capita GDP have a positive and statistically significant effect on per capita energy consumption (and vice-versa). This outcome validates the feed-back hypothesis in the long-run.

The rest of the paper is structured as follows. Section 2 outlines the empirical methodology, describes the data, displays and discusses the empirical results. The final section concludes.

II. DATA AND EMPIRICAL METHODOLOGY

2.1 Data

This paper employs annual data from 1989 to 2014 for four emerging countries: Brazil, Russia, India and China - known in the literature as the BRICs countries. The data are available for Brazil, China and India starting with 1976 and for Russia starting with 1989. To have a balanced data panel, we retained the 1989-2014 period. These countries accounted for approximately half of the economic growth in emerging markets over the past decade. This growth differential may reflect the potential role of BRICs for global energy markets going forward. In this study, we use data on real GDP per capita in constant 2000 U.S. dollars as a proxy for measuring the economic growth (G) and on energy use measured in kilograms of oil equivalent per capita (E) for the energy consumption per capita. Since all variables are in natural logarithms, each estimated coefficient is a constant elasticity of the dependent variable with respect to the independent variable. All data are given by World Bank database.

The descriptive statistics on the selected variables for each country are displayed in Table 1. The highest level of GDP per capita is reaching by Brazil (11797,5 US dollars) whilst the lowest level is for India (540,5 dollars). The lowest value of energy consumption per capita corresponds to India (344,7) while the highest level is reaching by Russia (5928,8) followed by China (2226,3).

TABLE 1
MAIN DESCRIPTIVE STATISTICS BY COUNTRY

Country	Statistics	Energy use per capita	GDP per capita
Brazil	Mean	1115,6	9263,6
	Median	1078,2	8743,9
	Std. Deviation	150,5	1238,7
	Minimum	929,0	7735,5
	Maximum	1437,8	11797,4
Russia	Mean	4739,6	8409,9
	Median	4540,9	8360,8
	Std. Deviation	570,5	2074,5
	Minimum	3981,5	5505,6
	Maximum	5928,8	11615,7
India	Mean	443,1	918,1
	Median	418,9	818,5
	Std. Deviation	79,5	331,9
	Minimum	344,7	540,5
	Maximum	606,1	1603,7
China	Mean	1198,4	2409,1
	Median	932,6	1893,5
	Std. Deviation	473,3	1526,2
	Minimum	724,1	708,8
	Maximum	2226,3	5652,4

Note: the selected variables are in levels.

The figures 1 and 2 show the evolution of GDP per capita and of energy consumption per capita in BRIC's countries. Both variables are in levels. India has the lowest evolution of energy consumption per capita while Russia followed by China have the highest trends of energy consumption per capita. Regarding the evolution of GDP per capita, Brazil recorded the highest levels of GDP per capita and India the lowest level of GDP per capita during the selected period 1989-2014.

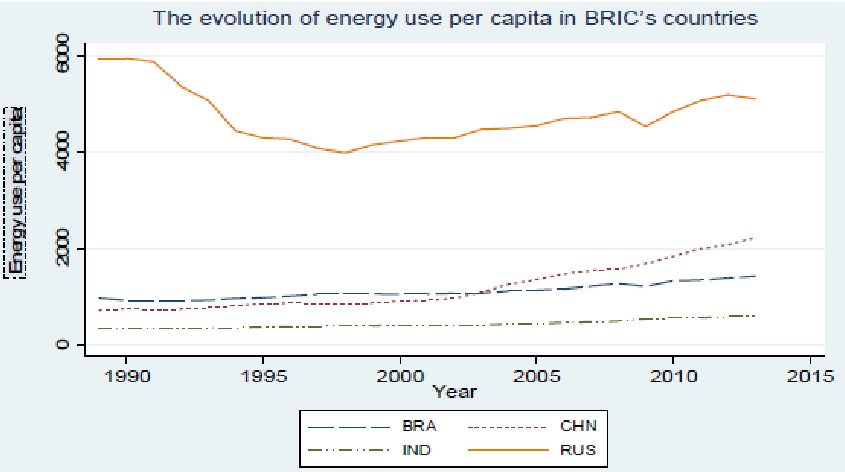

FIG. 1: THE EVOLUTION OF ENERGY USE PER CAPITA IN BRIC'S COUNTRIES

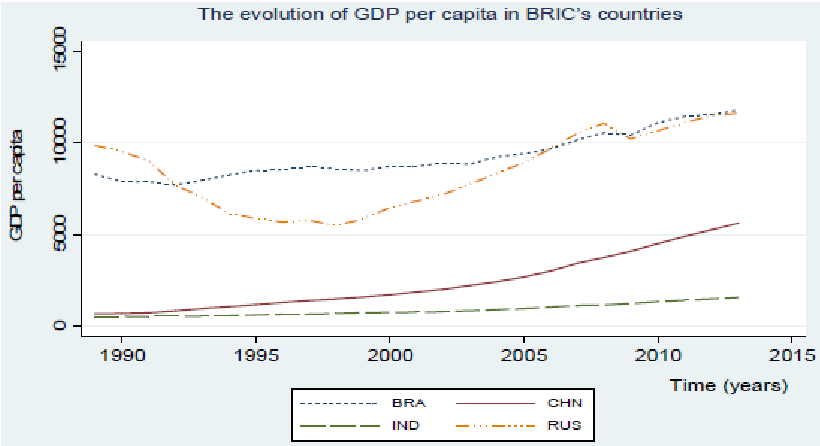

FIG. 2: THE EVOLUTION OF GDP PER CAPITA IN BRIC'S COUNTRIES

2.2 Methodology and results

2.2.1 Exploring cross-sectional dependence

The first step is to study the cross-section dependence hypothesis to see if data are cross-sectionally correlated. Interdependencies between BRIC may be explained by common shocks with diverse effects across countries (e.g., the recent financial crisis, oil shocks, and political shocks) and other unobserved components due, for example, to some trade agreements. We apply the Pesaran (2004) test based on pair-wise correlation coefficients and display the results in the table 2. The null hypothesis of no cross-sectional dependence is strongly rejected at the 1% level of significance for both variables implying that variables require a comparable dynamics to the countries.

TABLE 2
CROSS SECTION DEPENDENCE RESULTS OF PESARAN (CD)

	PANEL: VARIABLES IN LOG			
	CD	p-value	corr	abs(corr)
BRICs				
Energy use per capita	5.72[a]	0.00	0.467	0.515
GDP per capita	9.89[a]	0.00	0.807	0.807

Notes: (i) a means significant at the 1% level; (ii) Under the null hypothesis of cross-section independence CD ~ N(0,1); (iii) computations are with Stata program.

2.2.2 Panel unit root results

The second step is to check for the order of integration of our variables because the cointegration tests are valid only if variables have the same order of integration. Given that the Pesaran (2004) test shows evidence in favor of cross-section correlation between BRICs economies, we apply the second generation panel unit root test of Pesaran (2007). Under the null hypothesis, the test allows for nonstationarity and cross-section dependence. Results of table 3 show that the selected variables (in levels) are nonstationary (i.e., I(1)).

TABLE 3
THE PESARAN (2007) TEST RESULTS

Tests for BRICs	Pesaran (2007) CIPS (level)
Energy consumption per capita	0.579 (0.719)
GDP per capita	-0.996 (0.160)
Nb of years	26

Notes: the values in brackets are the associated probabilities; the selected models are with trend and constant, lags is 1 for GDP and energy use; variables in levels (log).

2.2.3 Panel cointegration analysis

The previous results show that there are strong interdependencies between countries. Second-generation cointegration tests assuming the cross-section dependence in cointegrating vectors can be applied such as the Westerlund (2007) test. The test assumes under the null hypothesis the absence of cointegration and the existence of an error correction term for individual panel members (with the group-mean statistics - Gt and Ga) and/or for the panel as a whole (with the panel statistics - Pt and Pa) without any common-factor restriction. As explained by Westerlund (2007), the test is general enough to account for a large degree of heterogeneity, both in the long-run cointegrating relationship and in the short-run dynamic, and for dependence within, as well as across, the cross-sectional units. Table 4 shows the results of the Westerlund (2007) test for models with constant only. Two statistics show evidence of cointegration at 5% statistical significance for the panel as a whole (Pt), and, at least, for one of the countries (as shown by Gt statistic).

TABLE 4
THE WESTERLUND (2007) COINTEGRATION TEST RESULTS FOR BRICS: EC – GDP

Statistics with constant and trend	Value	Z-value	P-value
Gt	-2.661**	-1.954	0.025
Ga	-5.189	0.743	0.771
Pt	-4.657**	-1.686	0.046
Pa	-5.172	-0.356	0.361

*Note: i) ***p<0.01, **p<0.05, *p<0.10; ii) the p-values are based on the normal distribution; (ii) the average AIC selected lag length is 3 and the average AIC selected lead length is 2.*

Overall, the results indicate that variables are integrated of order one and are cointegrated. Hence, the outcomes enable exploring the long-run impact of energy consumption on economic activity (and vice-versa). To estimate these long-run relationships, we apply the Dynamic Ordinary Least Squares (DOLS). Even if the Fully Modified Least Squares (FMOLS) model is not validated by the cross-section dependence results of Pesaran (2004) test, we present these results for comparison purposes in the second column of tables 5 and 6.

TABLE 5
LONG-RUN PANEL ESTIMATORS (DEPENDENT VARIABLE – REAL GDP PER CAPITA)

Independent Variables	FMOLS	DOLS
Model with constant		
Energy consumption per cap	1.623*** (0.102)	1.687*** (0.118)
Nb of panel observations	96	88
Model with linear trend		
Energy consumption per cap	1.029*** (0.144)	0.865*** (0.139)
Nb of panel observations	96	88

*Note: ***p<0.01, **p<0.05; *p<0.10; constant and trend are integrated in last models (lag=1; lead=1) with panel group FMOLS and DOLS; the standard errors are in the parenthesis.*

In the models including a linear trend, results of table 5 show that a 1% increase in energy use per capita raises GDP per capita by a value between 1.03% (in the FMOLS) and 0.87% (in the DOLS). In summary, the results of this set of estimations (see table 5) show that energy variable included in the models has a long-run impact on the GDP growth per capita. Both models (FMOLS and DOLS) indicate a positive and significant effect of the energy consumption per capita on the economic activity. Overall, the results are quasi-similar in magnitude (in the models with constant only) and sign across these two techniques.

Regarding the energy consumption per capita equation, the results of models with linear trend suggest that a 1% increase in GDP per capita increases energy use per capita by a value between 0.58% (in the FMOLS) and 0.67% (in the DOLS).

TABLE 6
LONG-RUN PANEL ESTIMATORS (DEPENDENT VARIABLE – ENERGY USE PER CAPITA)

Independent Variables	FMOLS	DOLS
Model with constant		
GDP per cap	0.534 *** (0.033)	0.556*** (0.032)
R-squared	0.992	0.996
Nb of panel observations	96	88
Model with linear trend		
GDP per cap	0.579*** (0.082)	0.665*** (0.104)
Nb of panel observations	96	88

*Note: ***p<0.01, **p<0.05; *p<0.10; only constant are integrated in models with panel group FMOLS and DOLS; the standard errors are in the parenthesis.*

III. CONCLUSION

This paper explores the long-run relationship between energy consumption and economic growth for BRICs countries over the 1989-2014 period (given the availability of data). Our data suggest the use of panel cointegration methods. In the models including a linear trend, outcomes show evidence in favor of a long-run positive effect of energy use per capita on the per capita GDP. A 1% increase in energy consumption per capita increases the real GDP per capita by about 0.87% (in the DOLS model). Furthermore, the effect of economic activity on energy use is also positive and significant because a 1% increase in GDP per capita increases energy use per capita by a value of 0.67% (in the DOLS model with a linear trend). Overall, the results validate the feed-back hypothesis and show that energy use is an important input in the production function. In terms of policy implications, energy saving policy and efficiency enhancement stimulates economic growth.

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