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Causality Relationship between Energy Consumption and Economic Growth in Brazil

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Abstract

This study has investigated the relationship between energy consumption and economic growth in Brazil during the period of 1980-2008. The co-integration test indicates a long-run equilibrium relationship between variables, and energy consumption appears to be real GDP elastic. This elasticity suggests that energy consumption has a great positive influence on changes in income. The causality results from the error correction model reveal a unidirectional short-run causality from energy consumption to economic growth and a bidirectional strong causality between them. These findings suggest that Brazil should adopt a dual strategy of increasing investment in energy infrastructure, and stepping up energy conservation policies to reduce any unnecessary waste of energy, in order to avoid having a negative effect on economic growth by reducing energy consumption. In contrast, energy conservation is expected to increase the efficient use of energy and, therefore, enhance economic growth.

Keywords

Energy Consumption, Economic Growth, Granger Causality, Brazil

1. Introduction

Energy is the foundation of economic development and constitutes one of the vital infrastructure investments in social development. Both economy and energy consumption in Brazil have been growing rapidly. In the recent five years (2003-2008), Brazil has experienced greater growth rates in both energy use (4.18%) and income

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(4.81%) than the global growth rates for corresponding variables. The world's recent five-year growth rates in energy use and real GDP are 2.97% and 3.43%, respectively. The Olympic Committee has chosen Brazil as the host country for the 2016 Olympic Games, highlighting the fact that Brazil is one of the future bright stars of the world. Official energy projections for Brazil indicate a continuing increase in demand for energy, in the next two decades.

There are numerous studies that deal with the causality relationship between energy consumption and economic growth. The findings from the studies vary not only across countries but also across methodologies for the same country. In a summary of the literature on the causal relationship between energy consumption and economic growth, there is evidence to support bidirectional or unidirectional causality, or no causality, between energy consumption and economic growth.

Evidence in either direction will have a significant bearing on policy. If, for example, there is unidirectional causality running from economic growth to energy consumption, it could imply that energy conservation policies may be implemented with little or no adverse effect on economic growth. Unidirectional causality running from economic growth to energy consumption was revealed by Ghosh [1] for India, by Mozumder and Marathe [2] for Bangladesh, by Narayan and Smyth [3] for Australia, by Yoo [4] for Indonesia and Thailand, and by Chen *et al.* [5] for Korea, Singapore, India, Malaysia and the Philippines.

In contrast, if a unidirectional causality runs from energy consumption to economic growth, reducing energy consumption could lead to a fall in economic growth while increasing it may contribute towards a country's economic growth. Unidirectional causality running from energy consumption to economic growth was revealed by Shiu and Lam [6] and Yuan *et al.* [7] for China, by Wolde-Rufael [8] for Shanghai, China, by Ho and Siu [9] for Hong Kung, by Pao *et al.* [10] for MIST countries, by Lee and Chang [11] for Taiwan, and by Chen *et al.* [5] for Indonesia.

On the other hand, if bidirectional causality is found, economic growth may demand more energy whereas more energy consumption may induce economic growth. Energy consumption and economic growth may complement each other and energy conservation measures may negatively affect economic growth. For example, Jumbe [12] for Malawi, Tang [13] and Yoo [4] for Malaysia, Yoo [4] for Singapore, Morimoto and Hope [14] for Sri Lanka, and Pao and Fu [15] [16] for Brazil found bidirectional causality between energy consumption and economic growth. In addition, Chen *et al.* [5] found bidirectional causality for 10 Asian countries using panel data.

Finally, no causality in either direction would indicate that energy conservation policies may not affect economic growth, and rise in real income may not affect electricity consumption. Chen *et al.* [5] found that there was no causality between economic growth and energy consumption in China, Taiwan and Thailand.

The purpose of this study is to investigate the causality relationship between energy consumption and economic growth, and to obtain policy implications from the results in Brazil. This purpose is accomplished by the following steps: First, stationarity and co-integration are tested; second, error-correction models are estimated to test for the Granger causality; finally, the F-tests are performed to determine the joint significance levels of causality between the two variables.

The remainder of this paper is organized as follows: Section 2 outlines the model and methodology. Section 3 discusses the data and empirical findings. The final section summarizes and concludes the paper.

For modeling purposes, all of the data were converted into natural logarithms prior to conducting the empirical analysis. Thus, the series can be interpreted in growth terms after taking the first difference into account.

2. Model and Methodology

2.1. Model

Following the empirical literature in energy economics, it is plausible to form a long-run relationship between energy consumption and economic growth in linear logarithm form, as follows:

$$\mathrm{LEC}_t = \beta_0 + \beta_1 \mathrm{LGDP}_t + u_t, \quad (1)$$

where LEC and LGDP represent natural logarithms of energy consumption and real GDP, respectively. The error term, u_t, is assumed to be independent and identically distributed with a zero mean and a constant variance. The long-run income elasticity is given by:

$$\frac{\partial \text{LEC}}{\partial \text{LGDP}} = \beta_1 \tag{2}$$

The signs of β_1 is expected to be positive because a higher level of economic growth should stimulate energy use.

2.2. Econometric Methodology

The empirical analysis tests for the existence of a long-term relationship between the variables in Equation (1) while using the vector error-correction model to capture the Granger causality between variables. A three-step procedure is performed. First, we check the integration order of each variable, since various co-integration tests are only valid if the variables have the same order of integration. The three unit root tests Augmented Dickey-Fuller (ADF) [17], the Phillips-Perron (PP) [18] and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) [19] are used to investigate the stationarity and the integration order of the variables. In terms of literature, tests designed on the basis of the null hypothesis that a series is $I(1)$ have a low power of rejecting the null. Hence, KPSS is sometimes used to complement the widely used ADF and PP tests in order to obtain robust results.

Second, when all of the series of the same order are integrated, the Johansen maximum likelihood method [20] is used to test the co-integration relationship between the variables in Equation (1). If co-integration exists among the variables, OLS applied to estimate Equation (1) does not lead to a spurious regression result. Furthermore, the parameters estimated by OLS are super-consistent [21]. The existence of co-integration indicates that there are long-run equilibrium relationships between the variables, and thereby, Granger causality exists between them in at least one direction [22] [23].

Finally, if all of the variables are $I(1)$ and co-integrated, the error correction model (ECM) is used for correcting any disequilibrium in the co-integration relationship, captured by the error-correction term (ECT), as well as testing for long-run and short-run causality among the co-integrated variables. The ECM for Equation (1) is specified as follows:

$$\Delta\text{LEC}_t = \gamma_{10} + \sum_{i=1}^{n_1}\gamma_{11i}\Delta\text{LEC}_{t-i} + \sum_{i=1}^{k_1}\gamma_{12i}\Delta\text{LGDP}_{t-i} + \delta_1\text{ECT}_{t-1} + \mu_{1t} \tag{3a}$$

$$\Delta\text{LGDP}_t = \gamma_{20} + \sum_{i=1}^{n_2}\gamma_{21i}\Delta\text{LGDP}_{t-i} + \sum_{i=1}^{k_2}\gamma_{22i}\Delta\text{LEC}_{t-i} + \delta_2\text{ECT}_{t-1} + \mu_{2t} \tag{3b}$$

where

$$\text{ECT}_{t-1} = \text{LEC}_{t-1} - b_0 - b_1\text{LGDP}_{t-1} \tag{4}$$

is derived from the long-term co-integration relationship described in Equation (1). The sign Δ is the first-difference operator; the optimum lag lengths n_i and k_i are determined on the basis of Akaike's information criteria (AIC); and μ_{it} are the serially uncorrelated error terms. The parameter δ_1 is interpreted as being the speed of the adjustment coefficient which measures the speed at which the values of LEC come back to long-term equilibrium levels, once LEC violates the long-run equilibrium relationship. The negative sign of the estimated speed of adjustment coefficient is in accord with the convergence toward long run equilibrium [24].

The ECM represented by Equation (3) includes both the dependent variables with their own lags and the previous disequilibrium in terms of $\text{ECT}_{t\text{-}1}$. This specification can test the short-run and long-run causality among co-integrated variables. In terms of short-run causality in Equation (3), the causality runs from the real output to energy consumption if the joint null hypothesis, $\gamma_{12i} = 0, \forall i$ is rejected via a Wald test, whereas the causality runs from energy consumption to the real output if the joint null hypothesis $\gamma_{21i} = 0, \forall i$ is rejected. With respect to long-run causality if the null hypothesis $\delta_1 = 0$ is rejected, energy consumption respond to deviations from the long-run disequilibrium. If the null hypothesis $\delta_2 = 0$ is rejected, then the real output responds to deviations from the long-run equilibrium. Finally, the strong Granger-causality runs from the real output to energy consumption if the null hypothesis $\gamma_{12i} = \delta_1 = 0, \forall i$ is rejected, whereas the strong Granger-causality runs from energy consumption to real output if the null hypothesis $\gamma_{21i} = \delta_2 = 0, \forall i$ is rejected.

4. Empirical Findings

This study collects annual data on energy consumption and real GDP for the period between 1980 and 2008 from the Energy Information Administration (EIA) and the World Development Indicators (WDI). Real GDP is measured in US dollars at 2000 prices. Energy consumption is measured in BTU (British thermal unit). **Table 1** displays the summary statistics associated with the two variables.

Figure 1 shows the change trend of each series for Brazil, all of which have increased across time. The energy consumption than the real GDP has exhibited a larger coefficient of variation (CV) shown in **Table 1**. **Table 2** shows average percentage growth rates in the years to 2008 of each series. Fifteen-year, ten-year, and five-year growth rates are calculated as the growth between 1993 and 2008, 1998 and 2008, and 2003 and 2008, respectively. In the most recent five years (2003-2008), Brazil has experienced a greater growth rates in both energy use (4.18%) and income (4.81%) than the global growth rates for corresponding variables. The world's most recent five-year growth rates in energy use and real GDP are 2.97% and 3.43%, respectively.

For the time period between 1980 and 2008, the energy consumption-income relationship (**Figure 2**) shows a monotonic increase in Brazil. Therefore, Equation (1) is employed to examine how the energy consumption and economic growth are related in the long-run. Both the values of adjusted R^2 and Jarque and Bera (JB) statistic [25] shown in **Table 3** indicate Equation (1) is appropriate to test whether the two series are co-integrated. **Table 4** shows the stationarity results for both LEC and LGDP through three different unit root tests, namely ADF, PP, and KPSS. All of the series appear to contain a unit root in their levels but are stationary in their first differ-

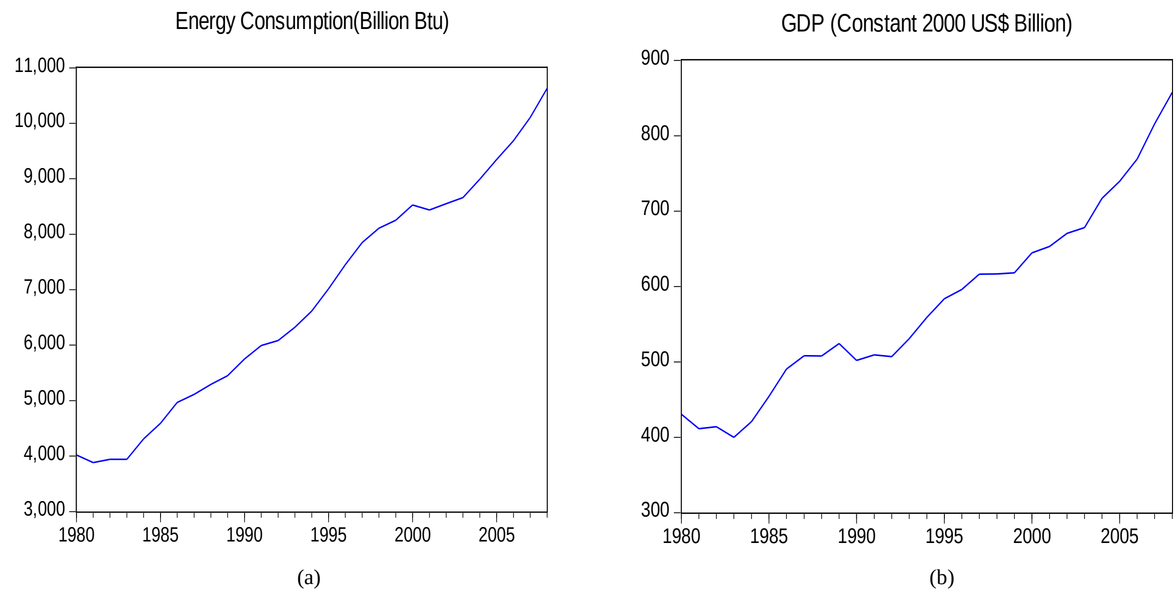

Figure 1. Time series plots of the energy consumption and real GDP, 1980-2008.

Table 1. Summary statistics for Brazil, 1980-2008.

Energy consumption (Billion Btu)			Real GDP (constant 2000 US$ Billions)		
Mean	S.D.	CV (%)	Mean	S.D.	CV (%)
6823.80	2063.677	30.24	577.411	124.920	21.64

Table 2. Average growth rates in percentages to 2008 for each variable.

	Brazil		World	
	Energy consumption	Real GDP	Energy consumption	Real GDP
15 year growth	5.15	3.25	2.41	3.11
10 year growth	2.75	3.36	2.57	3.09
5 year growth	4.18	4.81	2.97	3.43

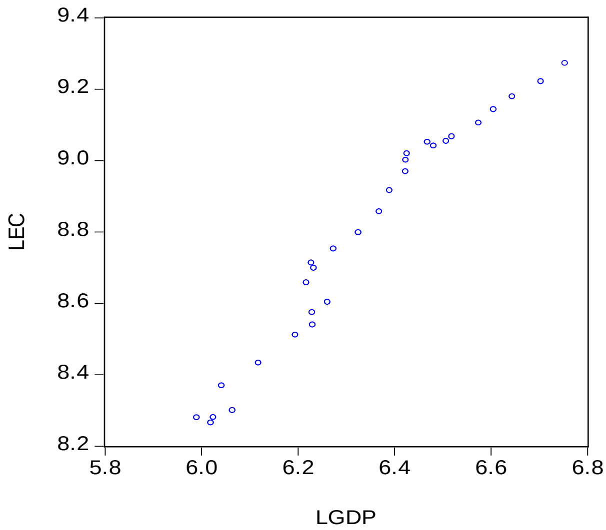

Figure 2. The ln(energy consumption)-ln(GDP) plots for Brazil, 1980-2008.

Table 3. Coefficients of Equations (1).

Dep. var.	Indep. var.				
	LGDP	Intercept	Adj-R2	JB	p-val.
LEC	1.454* (24.977)	−0.431 (−1.168)	0.9570	1.909	0.385

Note: Figures in parenthesis indicate t-statistics. * indicates the rejection of a null hypothesis at 1% level of significance.

Table 4. Results of unit roots tests.

	ADF		PP		KPSS	
	Level	1st diff.	Level	1st diff.	Level	1st diff.
LEC	−0.2761	−4.2798*	−0.3208	−4.2760*	0.6629**	0.0882
LGDP	2.2491	−4.2497*	0.5498	−4.2427*	0.6664**	0.1337

Note: All unit roots (except the KPSS) have a null hypothesis in that the series has a unit root against the alternative of being stationary. The null of KPSS states that the variable is stationary. Individual intercepts are included in test regressions. * and ** mean that the null of the unit root test is rejected at a 1% and 5% level. The lag lengths are selected using AIC.

ence, indicating that they are integrated at order one *i.e.*, *I*(1).

The next step is to test whether LEC and LGDP are co-integrated and **Table 5** shows the results of the Johansen test. The trace and eigenvalue tests reject the hypothesis of no co-integrating equation at a 5% level of significance, and have at least one co-integration equation existence. The estimated co-integrating vector normalized with respect to LEC is (1, 1.454) shown in **Table 3**. This implies that a 1% increase in the growth of income will lead to an increase of growth in energy consumption by 1.454% in the long run. Thus, in the long-run equilibrium, energy consumption appears to be real GDP elastic in Brazil.

Co-integration implies the existence of causality, at least in one direction. However, it does not indicate the direction of the causal relationship. Hence, to shed light on the direction of causality, ECM based causality tests are performed. The short-run χ^2-statistics, long-run *t*-statistics and joint *F*-statistics for Equation (3) are reported in **Table 6**. The short-run dynamics suggests unidirectional causality from energy consumption to real output. With respective to the long-run dynamics, the estimated coefficient of the ECT term is statistically significant with a negative sign in each equation, *i.e.* a change in one variable is expected to affect the other variables through a feedback system. This implies that there is a long term bi-directional causal relationship between them. Moreover, the estimated coefficients of the interaction terms are statistically significant in Equations (3a) and

(3b). This implies that a bidirectional strong Granger-causality is running between real output and energy consumption. In other words, whenever a shock occurs in the system, each variable makes a short-run adjustment to restore the long-run equilibrium. These findings are broadly consistent with the results of the BRICs as a whole [26] [27]. In **Figure 3**, we summarize all the causality results.

5. Conclusion and Policy Implications

This study has investigated the causality relationship between energy consumption and economic growth in Brazil during the period of 1980-2008. Granger causality test was used to examine the causal relationship between variables. Prior to testing for causality, the ADF, PP and KPSS unit root tests and Johansen co-integration rank test were used to examine the unit roots and the co-integration. The Johansen co-integration test indicates a long-run equilibrium relationship between energy consumption and economic growth, and energy consumption appears to be real GDP elastic. A 1% increase in the growth of income will lead to an increase of growth in energy consumption by 1.454% in the long run. This elasticity suggests that energy consumption has a great positive influence on changes in income.

A bidirectional strong Granger causality between economic growth and energy consumption implies that the two variables are jointly determined and affected at the same time. That is, an increase in energy consumption raises economic growth and vice versa. This can be explained by at least three factors: scale, technique effects, and energy efficiency. Firstly, the scale effect occurs as energy consumption increase with the size of the economy. Secondly, the energy-income relationship depends on the techniques of production. An improvement in the techniques of production, *i.e.*, the technique effect, may reduce the amount of energy use and increase profitability per unit of production. Finally, in pursuit of continuing economic growth, Brazil's government will need to put more effort into improving the energy efficiency of energy appliances and equipment, reducing the loss in power transmission and distribution, and introducing various kinds of tariff reforms to control energy consumption patterns. Figures for 2007 show that Brazil consumed 10046 Btu of energy for every dollar of GDP output at market exchange rates, which is only marginally higher than the world energy intensity of 9800 Btu. So, Brazil was the most efficient energy user. The disconcerting note in Brazil's record of energy use is that, while

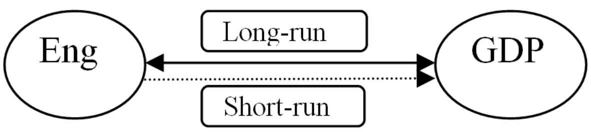

Figure 3. Causality results.

Table 5. Results of Johansen's co-integration test.

Eigenvalue	Trace Stat.	5% critical value	Max Eigen. Stat.	5% critical value	Number of co-integrations
0.673	36.765*	25.872	29.023*	19.387	None
0.258	7.742	12.518	7.742	12.518	At most 1

Note: The optimal lag lengths are selected using AIC. * indicates the rejection of a null hypothesis at 5% level of significance.

Table 6. Results of causality tests.

	Source of causation (independent variables)				
	Short-run		Long-run	Joint (short-run/long-run)	
	χ^2-statistics		*t*-statistics	*F*-statistics	
	ΔLEC	ΔLGDP	ECT	ΔLEC/ECT	ΔGDP/ECT
ΔLEC		1.116	−0.199*		5.640**
ΔLGDP	9.527*		−0.358*	11.962*	

Note: The optimal lag lengths are selected using AIC. * and ** indicate a 1% and 5% level of significance, respectively.

energy intensity has decreased by an annual average rate of 0.27% in the South and Central American region as a whole, Brazil has shown an annual average increase of 0.26% in energy intensity since the nineties. But it is still credible that the energy intensity in Brazil is almost a third lower than that of Venezuela, the largest source of oil in South America. However, Brazil is the 10^{th} largest energy consumer in the world and the third largest in the Western Hemisphere, behind the United States and Canada. Thus, an improvement in energy efficiency is essential. Thus, Brazil should adopt a dual strategy of increasing investment in energy infrastructure, and stepping up energy conservation policies to reduce any unnecessary waste of energy, in order to reduce emissions and avoid having a negative effect on economic growth by reducing energy consumption. In contrast, energy conservation is expected to increase the efficient use of energy and, therefore, enhance economic growth.

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