Journal of Economics and Sustainable Development
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online) DOI: 10.7176/JESD
Vol.10, No.14, 2019

Capital Formation, Energy Consumption and Economic Growth in Brazil: An ARDL Bound Testing Approach and Granger Causality

Indira M. Santos* Li Zhaohua
School of Economics, Huazhong University of Science and Technology, 1037 Luoyu Road, Wuhan, Hubei, China 430074

Abstract
This study analyses the short and long run impact of trade, energy consumption and capital formation on economic growth in Brazil. The time series considered is from the period of 1970-2014. By employing ARDL bound testing approach, the long and short run effects are estimated. With Error Correction model, the findings provide that gross capital formation and energy consumption has established a long run relationship with economic growth. In short run, though slightly but exports, along with energy consumption and capital formation are positively related with economic growth in Brazil. The results of granger causality exhibit a weak but bidirectional causality between gross capital formation and economic growth whereas, gross capital formation and economic growth are unidirectional granger causing energy consumption respectively. The study implies that policy makers need to increase the efficacy of energy sector promoting economic growth. Since the exports of the country are found non-significant in long run, it is important for the country to channelize the capital formation and energy sector within the country enhancing exports to evade from trade deficits.
DOI: 10.7176/JESD/10-14-03
Publication date:July 31st 2019

1. Introduction

Economic growth defines the level of economic strength of a state and in long run is an indicator of the living standards and quality of life. Growth can be fortified with different economic activities depending on the physical and human resources of the countries. As compared to developed countries, many developing countries though considerate in physical and human resources are found dealing with uncertainties leading to diminish economic growth. Being an important developing country of Latin America with access to Atlantic Ocean, having the ecological zone of Amazon, Brazil stands as an important Latin American country but has remained struggling to enhance the economic growth.

Exports are regarded as a key stimulating element of economic growth in many less developed and developing countries. Export led economic growth increases production, creates employment opportunities and facilitates the inflow of foreign exchange. Between 1960-1996, the trends of exports have similarities but have remained fluctuating from past few decades (Dinç and Gokmen 2019). Jenkins (2015) establishes that the rising of export-oriented industries of China contributed to the relative deindustrialization that caused “primarization” of Brazilian exports. Though the exports has increased significantly from 60 billion in 2002 to 240 billion in 2012 (SECEX, 2013), Jenkins (2015) believes that the export growth lacks sustainability.

Despite the volatile growth of trade in past four decades, Brazil is one of the largest energy consumers and is facing challenges of greenhouse gases reductions. In its energy mix, Brazil constitutes 57% of fossil fuels (Enerdata, 2014). Energy consumption also significantly contributes to economic growth establishing the fact that economic development and energy consumption is closely related with each other (Kraft and Kraft, 1978). Along with rising energy consumption for high GDP growth, pollution is a rising concern. Brazil, in this regard, has a unique role as a part of the 10 big economies of the world and has one of the greatest ecosystems of the planet. Friedl and Getzner (2003) builds the argument that with the call of Kyoto protocol to reduce the percentage of greenhouse gas emissions, the energy sector of many developing countries target to either reduce the energy usage or to transfer it from non-renewable to renewable energy sources. To moderate such emissions, countries like Brazil may face reductions in energy usage which may cause the slow-down of economic growth in country. As a necessary element for economic growth, reduction or transfer of energy usage from one source to another may affect different economic sectors of the country.

Being an important component of many developing countries of Latin America, gross capital formation (physical capital formation) has always been associated with economic growth of the countries. Baumik and Banik (2006) studied that the foreign direct investments with high natural resources leads to efficient capital formation and that skilled labour adds to increase the economic growth of the country. Bal et al. (2016) provides that capital formation is inherently interlinked with economic growth process of the developing economy like India. Therefore, it is important to see if the gross capital formation has a relationship with economic growth in Brazil too or other sectors are considerate.

This study aims to add to the research literature of endogenous-growth hypothesis, emphasizing on the short and long run relationship between energy consumption, trade, capital formation and economic growth in Brazil. It also aims to fill the gap of studies where it analyses the contribution of trade and capital formation and energy to the equation in the case of Brazil. For this study it will be used the ARDL bound testing approach and providing the evidence of the direction of causality among the variables by using Granger Causality analysis.

The ARDL method by Pesaran et al. (2001) has advantages over other estimators. Because it does not require testing for unit roots, it can indicate which variable should be the dependent variable and it calculates both short and long run estimates through linear transformation technique and its suitable in case of mixed stationarity at I (0) and I (1). There are several studies that used ARDL approach: Sami and Makun (2011) found that there is a significant relation among trade, energy consumption and economic development in Brazil; Talib and Fan (2019) applied the method in Pakistan and concluded a unidirectional causality between manufacturing and economic growth and a bidirectional causality between energy consumption and manufacturing; Adebola (2011) found an unidirectional causality between energy consumption and economic growth and another unidirectional causality between capital formation and economic growth in Botswana; Akalpler and Hove (2019) established the long term relation between capital formation and trade with economic growth in India; Chen et al. (2019) applied the model and concluded a direct causality between economic growth and CO2 emissions in China; Ahmad and Du (2017) established the direct causality between capital formation and energy consumption with economic growth in Iran.

Engle and Granger (1987) integrated the concept of cointegration into causality, stating that causal relations among variables can be examined within the framework of the ECM. A time series (X) is said to Granger-cause another time series (Y) if the prediction error of current Y declines by using past values of X in addition to past values of Y, the error correction term contains the information of long run causality. Hence, significance of each explanatory variable lags depict short run causality. On the other hand, a negative and statistical significant error correction term is assumed to signify long run causality.

The paper follows the subsequent structure: Section 2 explains the data, Section 3 focuses on the methodologies utilized for this study, Section 4 presents the results and Section 5 delivers the conclusion.

2. Data Description

The variables for this study have been taken from World Development Indicators (WDI), from the available period of 1970-2014. It was considered as variables GDP per capita (constant 2010 US$), Exports of goods and services (constant 2010 US$), Energy use (kg of oil equivalent per capita) and Gross capital formation (constant 2010 US$). A log of all variables was taken to harmonize the data. Table 1 presents more details of the data.

Table 1: Summary Stat

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP/cap	44	9.039207	0.1851104	8.538875	9.385589
Exports	44	25.04478	0.9078992	23.30011	26.26529
Energy Use	44	6.926138	0.1725459	6.570937	7.303121
Capital	44	26.34602	0.3637411	25.30428	26.99252

3. Methodology

Following Pesaran et al. (2001), this study relies on the ARDL bound testing method for calculating both short and long run estimates through linear transformation technique and more suitable in case of mixed stationarity at I(0) and I(1), the relationship between total energy consumption, economic growth, exports and capital is modeled as follows:

$$\Delta EG_t = \alpha_0 + \sum_{i=1}^{f} \omega_i \Delta EG_{t-i} + \sum_{i=0}^{g} \delta_i \Delta EXP_{t-i} + \sum_{i=0}^{h} \phi_i \Delta GCF_{t-i} + \sum_{i=0}^{k} \varphi_i \Delta ENERGY_{t-i} + \gamma_1 EG_{t-1} + \gamma_2 EXP_{t-1} + \gamma_3 GCF_{t-1} + \gamma_4 ENERGY_{t-1} + \mu_t$$

Where Δ is the first difference operator; ω, δ, ϕ and φ are the coefficients for EG, EXP, GCF and ENERGY; u_t is the error term; and f, g, h, k is the lag length selected by Akaike Information Criteria (AIC). Later, it has been conducted Durbin Watson (DW) and LM test for autocorrelation and white test for heteroskedasticity. As the next step, it was conducted Durbin Watson (DW) and LM test for autocorrelation and white test for heteroskedasticity. To find the direction of causality, the Granger Causality was applied considering the framework of VECM:

$$\Delta EG_t = \alpha_0 + \sum_{i=1}^{q} \partial_i \Delta EG_{t-i} + \sum_{i=0}^{r} \emptyset_i \Delta EXP_{t-i} + \sum_{i=0}^{s} \theta_i \Delta GCF_{t-i} + \sum_{i=0}^{u} \vartheta_i \Delta ENERGY_{t-i} + \rho_3 ECM_{t-1} + \varepsilon_t$$

Where Δ is the first difference operator; $\partial, \emptyset, \theta$ and ϑ are the coefficients EG, EXP, GCF and ENERGY; u_t is the error term; and f, g, h is the lag length selected by Akaike Information Criteria (AIC). ECM_{t-1} is the error correction term in consideration of long-run relationship. Whereas, ε_t its coefficient is the speed adjustment to the long run equilibrium.

4. Results

As can be seen in the graphs of Figure 1, Economic Growth (EG) and Exports (EXP) in Brazil has never followed a steady trend, being constantly fluctuating, with a significant drop in exports in 2009. Whereas in Energy (ENERGY), there is also a significant drop in 2009. In the same time period, Capital Formation (GCF) is the most stable variable, among all the variables taken into consideration. With such a fluctuating trend of the variables it can not be said that which variable determines the economic growth. Therefore, empirical analysis is held important to analyze the variables considered responsible for the economic growth.

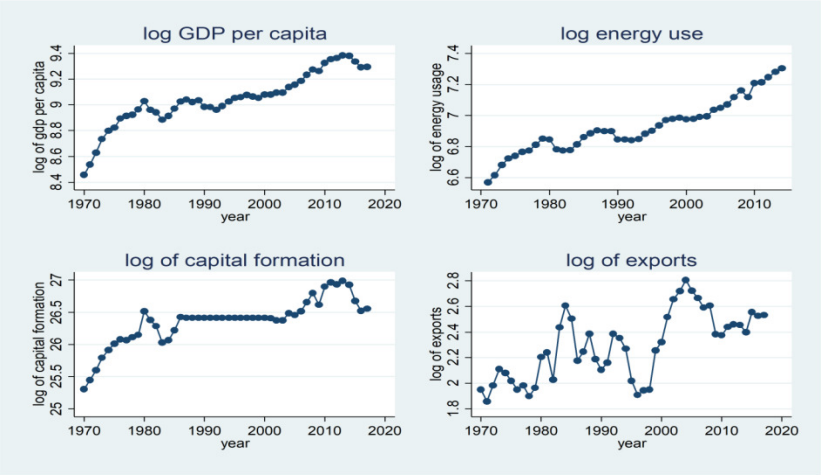

Figure 1: Graphs
Time trends of EG (log Economic Growth), ENERGY (log of energy usage), EXP (log export growth), GCF (log capital formation). The time series is from 1970-2014

4.1 Unit Root Analysis

To initiate the analysis, it is important to consider the level of stationarity of the variable taken. Table 2 in this regard, presents the estimated the results of unit root tests results of unit root tests at level and at first difference. To avoid inconsistency in the results and any variables integrated with order 2 is not allowed to use ARDL-bound testing approach, hence, it is necessary to check for the level of stationarity. For the empirical analysis, it has been conducted the Augmented Dickey Fuller (ADF) test by Dickey and Fuller (1979). By conducting the test, table 2 presents the Economic Growth (EG) is stationary at I (1), Exports (EXP), Capital (GCF) and Energy Consumption (ENERGY) were found stationary at first difference I (0) yet no variable has been found stationary at level 2, I(2). Being the results of integration found mixed and none of the variables found non-stationary above level 2, the methodology of ARDL is suitable for our analysis. To move further it is necessary to analyze the order of cointegration.

Table 2: Augmented Dickey Fuller Test (Unit root test)

Variable	I(0) At level				I(1) At first Difference			
	Without Trend		With Trend		Without Trend		With Trend	
	Z-Value	P-Value	Z-Value	P-Value	Z-Value	P-Value	Z-Value	P-Value
EG	-3.459	0.009	-3.371	0.055	-6.903	0.000	-6.881	0.000
EXP	-6.304	0.000	-6.884	0.000	-9.522	0.000	-9.396	0.000
GCF	-4.472	0.002	-4.472	0.002	-3.580	0.006	-3.563	0.033
ENERGY	-3.815	0.003	-3.853	0.014	-6.378	0.000	-6.369	0.000

Table 3: Integration decision: Mixed Stationarity

Variable	Integration
EG	I (1)
EXP	I (0)
GCF	I (0)
ENERGY	I (0)

4.2 Bound Testing Results

Table 4 present the results of the cointegration test, with values for upper and lower bound taken from Pesaran et al. (2001). The F statistics have been estimated with Bound Testing Approach. For optimal lag selection, it has been selected lag length 1 while taking VAR lag selection of Akaike information criteria (AIC). The confirmation of cointegration among variables is confirmed, as the value of F statistic lie above than 5.61.

Table 4: Bound Testing

Test Statistics		Values
F-Statistics		54.057
Bounds		
Significance	I(0) Bound	I(1) Bound
10%	2.72	3.77
5%	3.23	4.35
2.50%	3.69	4.89
1%	4.29	5.61

4.3 ARDL Long Run and Short Run Dynamics

As per consideration of the F-stat found above the upper bound presented in table 4, the long run estimation of ARDL stands valid. The long and short run estimates are presented in table 5, The results indicate that the coefficients of gross capital formation (GCF) and Energy use (ENERGY) are significant in short and long run found consistent with the findings of Adebola (2011), presenting the unidirectional relationship between capital formation and economic growth and Khobai (2018), whose research outcome exhibits the unidirectional relationship granger causing economic growth to energy consumption in the long run in BRICS countries. Moreover, Salazar-Nunez and Venegas-Martinez (2018) found that non-oil-producing countries, in the short and long term, GDP growth have bidirectional causality with capital formation. Ghani (2012) concluded, after presenting the estimates of 54 countries, that economic growth by itself increases the energy usage, not being affected by other factors, like trade liberalization. The same study provided that capital per labor also influences on energy consumption.

Along with other factors considered, Exports has shown little or no significance in short and long run respectively. The results estimate that the exports have remained insignificant in Brazil yet the capital formation and energy sector has increased economic growth in long run.

While considering the error correction term, it shows negative yet statistically significant relation confirming the earlier tests conducted for long run relationship of regressors with dependent variable. The coefficient of error correction term shows the speed adjustment for the long-run equilibrium corrected at 86 percent of its first quarter. Furthermore, it was possible to conduct Durbin Watson test for serial correlation and heteroscedasticity between the variables exhibit the non-rejection of null hypothesis. For serial correlation, it was conducted LM and Durbin-Watson (DW) tests and White test for heteroskedasticity. By conducting these tests, we exhibit the non-rejection of null hypothesis.

After establishing the long run relationship of gross capital formation and energy use with Economic Growth, it is important to observe the direction of causality. To estimate the causality, the VECM granger causality approach is applied. The results presented in table 6 indicate the granger causality test estimates exhibiting the bidirectional causality between capital formation and economic growth whereas, economic growth and capital formation is also granger causing energy consumption unidirectional The results highlight the importance of the sectors providing that though economic growth and capital formation are responsible for energy usage it is necessary for the policy makers to consider the renewable energy sources enhancing economic growth and capital formation within the country, supporting the argument of Bal et al. (2016) that capital formation has a strong relationship with economic growth in emerging economies and energy sector plays an important role in economic growth of the country (Kraft and Kraft, 1978). Whereas, the exports in the country has remained insignificant which also indicates that though in previous decades Brazil's exports has decreased due to deindustrialization effect it is needed to improve the export-led growth within the country with the consideration of renewable energy sources.

Table 5: ARDL long run and short run estimates

Dependent Variable: Economic Growth		
	Coeff(SE)	Tstat(Prob)
Long Run Analysis Lag length (1,1,0,0)		
EXP	0.0385	0.7
	(0.0551)	(0.489)
GCF	0.166***	4.86
	(0.0341)	(0.000)
ENERGY	0.695***	4.68
	(0.149)	(0.000)
Short Run Analysis, Lag Length (1,1,0,0)		
Δ EG(t-1)	0.139	1.84
	(0.0754)	(0.074)
Δ EXP	-0.0392	-1.15
	(0.0342)	(0.259)
Δ EXP(t-1)	0.0724*	2.15
	(0.0336)	(0.038)
Δ GCF	0.143***	4.72
	(0.0302)	(0.000)
Δ ENERGY	0.599***	5.33
	(0.112)	(0.000)
ECM(t-1)	-0.861***	-11.41
	(0.0754)	(0.000)
Intercept	-0.00171	-0.36
	(0.00473)	(0.72)
N	42	
R-sq	0.857	
Diagnostic Tests	Value	Prob
DW-Statistics	2.6861	
LM-Statistics (bgodfrey)	7.289	0.0691
Heteroscedasticity	22.37	0.3206

Note: Coefficients are reported with standard errors in brackets. ***, **, * indicate significance at 0.001, 0.01, and 0.05, respectively. Δ defines the first difference. All of the above estimations are based on the error correction model. (t-1) represents first lag. DW statistics and LM statistics test for autocorrelation and Heteroskedasticity is tested with White test.

Table 6: Granger Causality Test:

Variables	ΔEG	ΔEXP	ΔGCF	ΔEN
ΔEG	_	1.6201	6.1446*	1.9117
		(0.203)	(0.013)	(0.167)
ΔEXP	0.00281	_	1.00E-04	0.23105
	(0.958)		(0.992)	(0.631)
ΔGCF	5.218*	0.98803	_	0.16926
	(0.022)	**(0.320)**		**(0.681)**
ΔENERGY	4.6222*	0.25873	13.769***	_
	(0.032)	(0.611)	(0.000)	

Note: Coefficients are reported with probabilities in brackets. ***, **, and * indicate significance at 1%, 5% and 10% levels, respectively. Δ defines the first difference.

Figure 2:

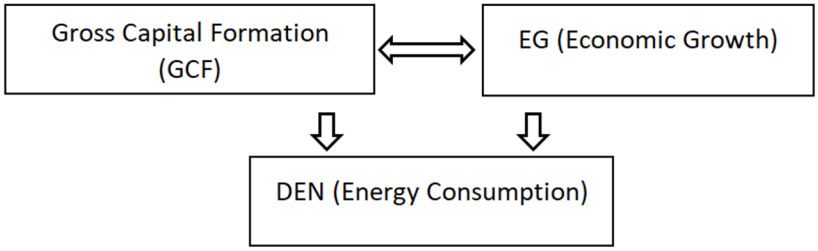

Figure 2 exhibits the significant outcomes of causality tests where capital formation shows bidirectional causality with economic growth whereas, a unidirectional causality has been found between energy consumption and gross capital formation and energy consumption with Economic Growth respectively.
⟺ Mention the bidirectional causality whereas, ⟹ represents unidirectional causality among variables.

5. Conclusion

This paper has examined the relationship between exports, energy consumption, capital formation and their impact in the economic growth of Brazil. The time series considered for this study is from 1970-2014. With the evidence of co-integration, we estimate the results with ARDL bound testing approach. The results indicate the positive significant relationship of the energy sector and gross capital formation with economic growth. In both short and long run, the capital formation and energy consumption has shown significance in Brazil. Whereas, country's exports though positive but have remained insignificant in the past four decades if considered along with other progressive sectors of growth in Brazil. By analyzing the direction of causality, we have estimated the results by granger causality approach. As per findings of Bal et al. (2016), capital formation is important for the economic growth in the emerging economies. In this regard, our results exhibit the bidirectional causality between capital formation and economic growth whereas, capital formation and economic growth finds unidirectional causality with energy consumption. It exhibits that in past four decades, the capital formation has kept the level of sustained growth in the country whereas, energy sector has also been found unidirectional caused by economic growth and capital formation.

Being a country with ecological zone of Amazon, it is therefore, necessary to enhance the capital formation and economic growth while emphasizing on the renewable energy sources in Brazil. Moreover, it is important to increase the exports to enhance the export led growth in the country. Since the export growth in the country is relatively non-significant in long run it is important to consider its enhancement with the consideration of renewable energy sector.

6. References

1 Adebola, S. (2011). Electricity Consumption and Economic Growth: Trivariate investigation in Botswana with Capital Formation. *International Journal of Energy Economics and Policy* Vol. 1, No. 2, 2011, pp.32-46.

2 Ahmad N., Du L. (2017). Effects of energy production and CO2 emissions on economic growth in Iran: ARDL approach. *Energy* 123 (2017) 521-537.

3 Akalpler, E. Hove, S. (2019). Carbon emissions, energy use, real GDP per capita and trade matrix in the Indian economy-an ARDL approach. *Energy* 168 (2019) 1081-1093.

4 Bal, D. et al (2016). The Effects of Capital Formation on Economic Growth in India: Evidence from ARDL-bound Testing Approach. *Global Business Review* 17(6) 1–13.

5 Bhaumik, P.K., & Banik, A. (2006). FDI, skilled labour and the Caribbean's emerging competitive disadvantage. *Global Business Review*, 7(2), 175–193.

6 Chen, Y. et al. (2019). CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. *Renewable Energy* 131 (2019) 208-216.

7 Dickey, D. and Fuller, W. (1979). Distribution of estimators for autoregressive time series with unit root, *Journal of American Statistical Association*, Volume 74, pp. 421-431.

8 Dinç D. and Gokmen A. (2019). Export-led economic growth and the case of Brazil: An empirical research. *Journal of Transnational Management*, 24:2, 122-14.

9 Enerdata. (2014), World Energy Consumption: China and BRICS Slow, While the USA Restarts. Available: https://www.enerdata. net/publications/executive-briefing/world-energy-consumption-china-and-BRICS-slow-while-usa-restart.html

10 Engle, R. F., and Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica;* 55: 251-276

11 Friedl B, Getzner M. (2003). Determinants of CO2 emissions in a small open economy. *Ecol Econ* 2003; 45:133-48.

12 Ghani, G (2012). Does trade liberalization effect energy consumption? *Energy Policy* 43 (2012) 285–290

13 Jenkins, R. (2015). Is Chinese Competition Causing Deindustrialization in Brazil? *Latin American Perspectives*, Issue 205, Vol. 42 No. 6, November 2015, 42–63

14 Khobai, H (2018). Electricity Consumption and Economic Growth: A Panel Data Approach for Brazil, Russia, India, China and South Africa Countries. *International Journal of Energy Economics and Policy*, 2018, 8(3), 283-289.

15 Kraft J, Kraft A. (1978). On the relationship between energy and GNP. *J Energy Dev* 1978; 3:401-3.

16 Ministry of Industry, Foreign Trade and Services (2013). Estatísticas de comércio exterior. Brasilia: SECEX (Secretaria de Comércio Exterior). Available: http://www.desenvolvimento.gov.br/sitio/interna/interna.php?area=5&menu=576

17 Pesaran, M. et al (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*; May/Jun 2001; 16, 3; ProQuest pg. 289.

18 Salazar-Núñez, H. Venegas-Martínez, F. (2018). Impact of Energy Use and Gross Capital Formation on Economic Growth. A Panel Data Analysis in 73 Countries Grouped by Income Level and Oil Production. *EL TRIMESTRE ECONÓMICO*, vol. LXXXV (2), núm. 338, abril-junio de 2018, pp. 341-364.

19 Sami, J. and Makun, K. (2011). The Relationship between Exports, Electricity Consumption and Economic Growth: Empirical evidence from Brazil. *World Review of Business Research* Vol. 1. No. 5. November 2011. Pp.28-37.

20 Talib, M. and Fan, H. (2019). Energy Consumption, Manufacturing Output and Economic Growth in Pakistan: An ARDL Bound Testing Approach. *Journal of Economics and Sustainable Development*, Vol.10, No.6, 2019.