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ARDL BDM t-test and Robust Inference for the Long-Run Relationship Between Energy Consumption and Economic Growth in Nigeria: 1976-2015.

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Abstract

Although there is a voluminous literature focused on examining whether energy use granger causes growth of GDP or growth of GDP granger causes energy use, it is still inconclusive just as the understanding regarding the concept of growth which has been studied right from the time of Adam Smith, but yet still remains largely inconclusive. The results from different studies are ambiguous not only because of varying statistical techniques but also because of different parameters that have been used in these models. This paper tests, in a country specific context, the long-run relationship between energy access, and economic growth for Nigeria from 1976-2015 by employing (ARDL BDM t-test) Error Correction Mechanism tests for cointegration in a single-equation Framework. We adopt a three stage approach, consisting of unit root, cointegration and Granger causality tests to study the dynamic causal relationship between energy consumption, energy prices and growth. Results show there is a stable relationship between GDP, oil price and energy consumption. By estimating these long run relationships and testing for causality using the Toda Yammoto approach, we found evidence of unidirectional causality between energy consumption and GDP. This provides evidence for the energy growth hypothesis consistent in the literature. Thus if we cut back on our energy use, growth would abandon us.

Keywords: BDM-t test, Economic Growth, Cointegration, Energy Development
JEL Codes: Q43

1. Introduction

This research is focused not on the importance of energy in economic growth but rather the role of energy in achieving the long term rise in capacity of an economy to supply increasingly diverse economic goods to its population as professor Simon Kuznets conceptualize economic growth. Energy development, interpreted broadly to mean increased availability and use of energy services, is an integral part of enhanced economic development. For centuries economists have worshiped in the shrine of economic growth, preoccupied with the understanding of the growth of nations (Todaro & Smith, 2016). This simple but yet complex concept of growth have been studied continually since the days of Adam Smith. Subsequently, a literature has emerged that has focused on the existence of a relationship between energy consumption and economic growth. A feature of this literature has been to utilize a battery of test to investigate the integration properties of energy variables (Smyth & Narayan, 2015). Consequently this effort has produced a better understanding of the sources of economic growth. But again the subject has proved elusive, and many mysteries remain (Helpman, 2004). These reports tell us nothing besides the fact that energy has a disproportionate role in economic growth of both developed and developing countries. We do not know a lot as we should on the precise link that surrounds energy development. Most concern with energy development arises from the assumption that the character of future energy availability will have a major impact on the quality of life, and the level of economic activity is a primary measure of this quality. In addition, the analysis and results of the first Energy Modelling Forum (1977) study emphasized that the relationship between energy and GNP is neither one to one nor is it nonexistent. Thus interest in understanding the nature of the energy-economy link continues to intrigue researchers. We revisit energy and economic growth because there is an existing hypothesis that suggests the two are inseparable owing to the close interrelationship between them[1]. The difficult question is can energy demand growth be dampened further by higher energy prices without proportional reductions in economic activity?

Early literature dating back to the energy modeling forum downplayed the role of energy in economic growth. For instance, the fable of the Elephant and Rabbit applies to an aggregate view of the economy with a single output and two inputs. Using the US economy, (Hogan & Mann, 1977) represent the economy in terms of just two inputs—energy and all other items. As of the 1970, the value of primary energy inputs did not exceed 4% of the GNP. This relationship was assumed to represent something like an elephant –rabbit stew[2]. "If such a recipe contains just one rabbit (the energy sector) and one elephant (the rest of the economy), won't it still taste very much like the elephant stew"?

The fact that expanded availability and use of energy services is strongly associated with economic development still leaves open how important energy is as a causal factor in economic development. A more recent illustration of the importance accorded to energy development in economic development, is the call for affordable and clean energy utilization in the Sustainable Development Goals developed to achieve a better and more sustainable future for all**.**

Perhaps the expanded availability of electricity has contributed to progress recorded in improvement in the levels of living observed across both developed and developing countries. In examining the role of energy, the literature has focused on understanding whether the relationship between energy variable and non-energy variable is immutable or unimmutable? An answer to this question is important in designing an effective energy and environmental policy that will promote sustainable development (Menegaki, 2014)**.** A review of the recent literature points to the fact that the literature has given much consideration to how developing societies use energy, and less to how energy-using societies develop. This is evident in the recent stylized facts on energy (Csereklyei, Rubio-Varas, & Stern, 2016). The most significant conclusion coming from a review of the granger causality literature in energy economics is that, the direction of causality between energy consumption and economic variables has remained empirically elusive and controversial. In the light of the aforementioned, we revisit the debate with an application of cointegration testing in single equation framework, so as to understand the pattern of changes that has taken place in Nigeria.

The paper is organized as follows. Section 2 briefly reviews related studies regarding energy consumption in Nigeria, as well as multi country studies where Nigeria was

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[1] What has sustained this macroscopic relationship is the way in which the growth of capital seems to have been matched by growth in output per capita over a very long time period

[2] The small relative size of the energy sector motivates the metaphor of the elephant and the rabbit. It indicates that small changes in energy availability do not produce proportional changes in economic activity.

included among the countries in the panel. Section 3 highlights the model formulation, data and estimation strategy. Section 4 presents the results. Section 5 concludes the paper with future research directions.

2. Theoretical and Empirical Review.

Theoretical Review.

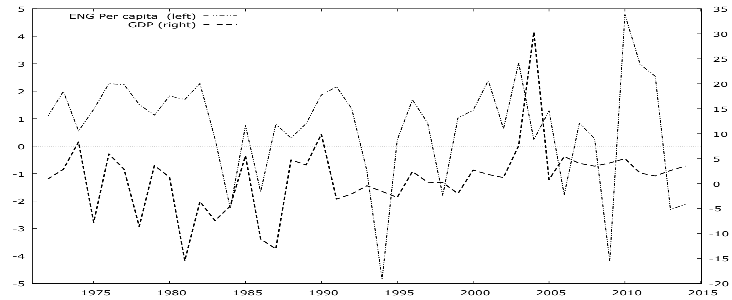
Economist views potential improvements in the productivity of labour, through the use of capital and of capital through improved technology. In the electricity type energy – GDP literature it is common to analyze economic relevance of energy by means of causality test of the energy-GDP relationship (Bruns & Gross, 2013; Ozturk & Acaravci, 2011). Usually the ARDL bounds testing approach to cointegration, the Engle and Granger (1987) causality test as well as batteries of test are applied to time series for developing countries as well as developed countries at varying levels of development to infer the nature and existence of causality. An understanding of the role of energy in the economy is a complex issue because energy availability affects every aspect of our life style from production to consumption. As an extension to the growth debate, energy economist have extended the analysis to understanding how aggregate energy as well as disaggregate energy type influence growth of an economy. From this argument a branch of literature has developed that tries to look at disaggregated energy consumption because what may be true for the use of electric power in smelting iron need not be true for the use of oil in automobiles. Uncertainty regarding the supply as well as regional differences also contributes to the difficulty in understanding the interactions among energy sector and the reminder of the economy[3]. Disaggregating various causality literature with respect to the parameter used, and direction of causality, Gross (2012) concludes that if different energy aggregates are used across studies, the results naturally differ by comparison. Although Toman and Jemelkova (2003) documents that energy plays a disproportionate role in economic development, it however is important to nearly any activity that is non-natural. Rafindadi and Ozturk (2016) rightly clarified the role of energy despite its disproportionate role. For instance energy is important in communication, transportation, education, health, financial operation and industrial operations.

Fig 1 shows a plot of growth energy consumption and GDP growth. The correlation of energy consumption with GDP suggests that energy is an important partner variable for a causality analysis with total GDP. However, in the light of the elephant rabbit fable, the question then becomes is consumption of energy also a relevant factor with respect to its market share? The movements further suggest that there is a positive correlation between energy and economic growth.

Gross (2012) rightly a point out that one major determinant for the declining energy intensity is the role of technological progress. In a analyzing technological progress and economic growth, Helpman (2004) explains the fact that “growth that is driven by general purpose technologies is different from growth driven by incremental innovations. Unlike incremental innovations, general purpose technologies such as steam engine, electricity and computer can trigger an uneven trajectory, which starts with a prolonged slowdown followed by a fast acceleration.”

[3] There is some evidence that the relationship between energy and economic growth is not immutable, but the degree of potential flexibility is disputed.

Fig 1. Plot of GDP and ENG conusmption



Empirical Review

Beginning with (Yemane Wolde-Rufael, 2009) for the case of African countries there is a relatively small subset of this literature which uses an augmented production function to examine the statistical properties between energy and economic growth. Similarly, beginning with (Iwayemi, Adenikinju, & Babatunde, 2010; Odhiambo, 2010; Ouedraogo, 2013b; Yemane Wolde-Rufael, 2014) there is a small subset of the literature that considers the relationship between energy consumption, disaggregated by type, and economic growth. There are also a few studies that have compared the relationship between both aggregate and disaggregated energy consumption and economic growth in alternative specifications. For instance see (Odhiambo, 2009b; Sa'ad, 2010).

OF the existing study for Nigeria, most use a bivariate framework to examine the relationship between energy consumption and economic growth (Akinlo, 2009; Sa'ad, 2010). Other studies use a multivariate framework where, in addition to economic growth and energy consumption, the model includes carbon emissions (Rafindadi, 2016), energy prices (Lean & Smyth, 2014; Ouedraogo, 2013a). One finding with most of these studies which have employed unit root testing as a precondition is that energy variables have a unit root. A summary of the literature suggests that findings with respect to Ganger causality between energy consumption and economic growth are mixed. For instance in the case of Malaysia (Lean & Smyth, 2014) documents that studies that employ the use of the multivariate framework, indicate that the direction of Granger causality is mixed and seems to depend on the ad hoc choice of the other variables other than energy consumption and economic growth included in the model.

Using a three-stage approach, consisting of panel unit root, panel cointegration and Granger causality tests model of energy consumption, energy prices and economic growth for selected West African States (1980-2008), (Ouedraogo, 2013b) finds the existence of long-run and causal relationships between energy consumption and economic growth for the sample of fifteen countries. A unidirectional causality was running from GDP to energy consumption in the short-run, and from energy consumption to GDP in the long-run.

In a related study (Ouedraogo, 2013a) investigated not aggregate energy but rather focused on electricity which is an important form of secondary energy using panel unit root, cointegration and causality tests. The result of the panel causality tests between real GDP and electricity consumption for the 15 countries revealed only a unidirectional long run causality running from electricity consumption to real GDP existed. In the case of Nigeria, the country specific result showed that 47% of Nigerian population had access to electricity. Cointegrating result for Nigeria showed a significant and positive long-run relationship with GDP with income elasticity of 0.44. The result also revealed no evidence of causality between energy consumption and income, indicating neutrality between energy consumption and income in the short run, no Granger causality between electricity consumption and income is found with respect to Nigeria in the short run However, there exists a long-run causality between electricity consumption growth. Esso (2010) investigates the long-run causal relationship between energy consumption and economic growth for 7 Sub-Saharan African countries for the period 1970–2007. For this purpose, the study use the Gregory and Hansen (1996) threshold cointegration approach and the Toda and Yamamoto version of Granger causality test. The results of the test show that energy consumption and economic growth are cointegrated. This further suggests that finding of long-run relationship is a stylized fact in the energy literature.

As discussed above, there are just few studies that model the relationship using energy prices, as a result this study follows the suggestion by Narayan (2015) that calls for more country specific study as against multi country studies. Consequently, we focus our attention on identifying specific country as against multi country study. This is so as to identify how results differ according to level of economic development.

3. Methodology

The test of the causal relationship among our variable is conducted in three stages. First, we test for the order of integration in GDP, energy consumption, and price series. Secondly, if they are integrated at order one I (1) we employ the BDM-t test (Banerjee, Dolado, & Mestre, 1998) Error correction Mechanism test for cointgertaion in a single-equation framework, to examine the long-run relationships among the variables. Our approach of utilizing the BDM-t test is because the t-ratio form of the ECM test has better power properties than the normalized bias form when the common factor restrictions are grossly violated. This test is superior to the bounds F test that has been relatively used in most literature which impose possibly common-factor restrictions in the estimation underlying the test. If the variables are cointegrated, the long -run cointegration vector is estimated using Ordinary Least Squares. Finally, we use the VAR models to test for the existence and direction of causality.

Estimation Strategy

The standard approach in the literature assumes a functional relationship between energy demand and the key explanatory variables of prices and income, see (Iwayemi et al., 2010; Ouedraogo, 2013b). A perception in the literature that a complex model with extensive input data produces more accurate results might not always be true. Moreover a model is simply a representation of our understanding. Complex models do not replace careful thinking. Therefore we employ a simple multivariate model as against the bivariate model because drawing specific economic conclusions with regards to single types of energy from bivariate causality analysis is difficult because of omitted variable bias (Bruns & Gross, 2013). Cointegration analysis is the appropriate approach to investigate the long-run relationship between energy consumption, prices and GDP.

Unit root test

To test for a unit root in each of the series we employ the LM unit root test with one structural break proposed by Lee and Strazicich (2004). Allowing for structural breaks is important giving that during the period considered, the Nigerian economy has experienced several shocks, such as the SAP era, the Global financial crisis and policy shifts which have potentially caused a break inn economic growth and energy consumption. If one does not allow for a break, this will reduce the power of the unit root test to reject the null in the presence of a break, therefore pointing towards a model mis-specification which comes with not one but multiple costs (Smyth & Narayan, 2015). The LM unit root test have better size properties and identify the break more accurately than the alternatives. We employ both the LM unit root test with one break in the intercept (Model A) and the LM unit root test with one break in the intercept and slope (Model C).

$$y_t = \delta Z_t + X_t, \; X_t = \beta X_{t-1} + \varepsilon_t \quad \text{--}\mathbf{3.1}$$

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \mu_t \quad \text{------------}\mathbf{3.2}$$

BDM -t test of no cointegration

Testing for cointegration has become an important facet of empirical analysis of economic time series, and various tests are being used. In this paper we use the BDM t-test[4], in a single equation framework proposed by Banerjee et al. (1998) to examine the cointegration between energy consumption and economic growth. Our choice of the variant of ADL models is premised on theoretical underpinning in the econometric literature, Smyth (2013) argued that with a single time series, if one or more of the variables, including energy consumption or production is stationary, the appropriate approach to testing for cointegration is the autoregressive distributed lag or bounds testing approach. This class of model has traditionally been used in the empirical literature to seek a tentatively adequate data characterization that encompasses rival models, displays parameter constancy, has martingale difference errors with respect to a selected information set and parsimoniously orthonomarlizes the regressors. There are several advantages of using the BDM t –test over other test such as the Engle and Granger (1987) and the Cochrane-Orcutt (1990) tests. (1) Here the limit distribution does not depend upon nuisance parameters but does depend on the dimension of the system. (2) cointegration statistics such as the Engle and Granger (1987) test, suffers in finite samples from imposing potentially invalid common-factor restrictions. Banerjee et al. (1998) have shown that when the restrictions are invalid, the power properties of the Corut Ochrane and Engel Granger test may have poor power properties. (3) a summary of empirical studies have shown that when the state of the art econometric techniques are used energy variables are infact stationary. This means they are I(0) in nature and further justifies our use of the BDM t test.

[4] We apply the level ARDL formulation instead of the ECM-ARDL form, and test the corresponding null hypothesis as specified in gretl estimation software.

The testing procedure has the following form:

$$\Delta \gamma_t = \alpha \Delta \chi_t + \beta(y_{t-1} - \lambda \chi_{t-1}) + \varepsilon_t \quad ..3.3$$

$$\Delta \chi_t = U_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

Where α, λ and x_t are k X 1 vectors of parameters and explanatory variables. The regressand y_t is a univariate process and β is a scalar; the initial conditions are, without loss of generality, set to zero and T is the sample size. The elements of x_t correspond to different regressors.

The ECM test statistics for cointegration, as suggested by Banerjee et al. (1998) is based upon estimating (1)by OLS. According to this procedure β is estimated by OLS from the unrestricted dynamic model**.**

$$\Delta \gamma_t = \alpha \Delta \chi_t + \beta \gamma_{t-1} + \theta \chi_{t-1} + \varepsilon_t = \alpha \Delta \chi_t + \Pi \mathcal{W}_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5$$

Where $w' = (y_t, x_t')$ and $\pi' = (\beta, \theta')$

Granger Causality Test

Granger causality testing has been the most common approach to determining the causal validity of energy-output models (Stern & Enflo, 2013). Therefore having found that there exists a long-run relationship between the variables, we then investigate the dynamic relationship using VAR models. The optimal lag order is selected following the minimum values of the Bayesian information criterion (BIC). In the energy growth literature, Gross (2012) provides a generally accepted concept of causality as a condition where 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. This study specifically employs the Toda Yamamoto hereafter (TY) procedure. The advantage of using the TY approach over the Engle Granger procedure is that (1) the TY procedure does not require pre-testing for the cointgerating properties of the system and thus avoids the potential bias associated with unit root and cointegration test. Therefore it can be applied regardless of whether a series is I(0), I(1) or I(2), not-cointgerated or cointegrated of an arbitrary order (Menyah & Wolde-Rufael, 2010).

The TY approach fits a standard vector auto regression model on level of the variables (not on their first differences) and therefore makes allowance for the long run information often ignored in systems that require first differencing and pre whitening (Odhiambo, 2010). The basic idea of the TY approach is to artificially augment the correct order, k, by the maximal order of integration, say d_{max}(Yemane Wolde-Rufael, 2009). To undertake the TY version of the Granger non-causality test, for VAR (2), (k = 1 and d_{max} =1) we estimate the following system equations:

$$\begin{bmatrix} LGDP_t \\ LENG_t \\ LaLP_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} LGDP_{t-1} \\ LENG_{t-1} \\ LaLP_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} LGDP_{t-2} \\ LENG_{t-2} \\ LaLP_{t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon LGDP_t \\ \varepsilon LENG_t \\ \varepsilon LaLP_t \end{bmatrix} \ldots\ldots\ldots\ldots 6$$

In equation (6) A_1 and A_2 are two 3 by 3 matrices of coefficients with A_0 being the 3 by 1 identity matrix, ε are the disturbance terms with zero mean and constant variance.

From equation (6) we can test the hypothesis that energy consumption (ENG) Granger causes economic growth (LGDP), in the following hypothesis: $H_0 = a^1{}_{12} = 0$, where $a^1{}_{12}$ is the coefficient of the energy variable in the first equation of the system presented in equation (6). Additionally we can test the opposite causality from economic growth to energy consumption in the following hypothesis: $H_0 = a^1{}_{21} = 0$, where $a^1{}_{21}$ is the coefficient of the economc growth variable in the second equation of the system presented in Eq. (6).

4. Empirical Results.

Unit Root Test

The study conduct several unit root test to make a case for stationarity or non stationarity of the variables used in the study. We do not present the results to conserve space, but the results show that the all series were I(1). Since our series are integrated of the same order, BDM-T test is the most appropriate approach for testing for cointegration while the Toda Yamamoto approach is the most appropriate approach for testing for causality.

Cointegration Test

In this section, the longrun relationship among [GDP, ENG, OILP] is examined using the BDM t-testing procedure. In the first procedure, the selection of lags is based on the Akaike Information Criteria and specification tests. To test for cointegration using the ECM t test the procedure depends on the significance of the lagged dependent variable. This is equivalent to testing the significance of the error-correction terms in the ECM reparametrization of the model. The decision rule is to reject the null of no cointegration if the t-statistics exceeds the upper bound critical value. The null of no cointegration is rejected at the 5 per cent level, based on (Banerjee et al., 1998) upper bound critical values.

Table 1 BDM boot strap t-test based on ARDL (1,1)

T –Statistics	t –statistics	Bootstrap p value
F_{lnGDP}(FGDP|LnENG,LnOILP)	3.138	0.330
F_{lnENG}(FENG|LnGDP,LnOILP)	2.708	0.349
F_{lnOIL}(FOILP|LnENG,LnGDP)	8.722	0.026**

*Notes * denotes rejection of the null of no contgertion at 5% significant level. We use the non-parametric bootstrap method with with replacement from the estimated residuals.*

Table 2 Estimate of the Long Run Relationship

Estimated Long-run coefficients, dependent variable, lnGDP			
Regressors	Coefficient	Standard error	t-ratio [probability)
OILP	-0.11	0.04	9.88[0.000]***
ENG	-2.47	0.97	-2.57[0.000]**
Constant	22.05	6.28	3.51[0.001]***

*Notes: *** and ** denote significant at 1% and 5% respectively.*

Specifically a 1% increase in OILP leads to -0.11% increase in economic growth, while a 1% increase in ENG increases output by only -2.47%. Surprisingly, the sign of the coefficient of the energy variable is negative. From an economic point of view, this is difficult to interpret, perhaps it suggest we are using energy inefficiently. Similarly, a negative longrun relationship between energy consumption and GDP has been reported for Nigeria (Yemane Wolde-Rufael, 2005, 2006; Yemane Wolde-Rufael, 2009) and South Africa (Odhiambo, 2009a).

Granger Causality Test

The Granger causality test is very sensitive to the selection of the lag length, we therefore use the minimum SIC criteria to select the optimum lag of the model. Selecting the appropriate lags in the causality testing is important because if the chosen lag length is less than the true lag length, then the omission of relevant lags can cause bias. In addition Menyah and Wolde-Rufael (2010) argued that in order to avoid spurious causality or spurious absence of causality, it is important to determine the optimal lag length k in the (granger causality equation). On the other hand if the chosen lag length is more than the true lag length, the irrelevant lags in the equation cause the estimates to be inefficient Having established the optimum lag length (k), the next step is to conduct Granger non-causality test by augmenting the VAR (k) by the maximum order of integration of the series, $d_{(max)}$ Table 3 presents results of the Granger non-causality tests. We find that there is a bidirectional causality running from OILP to GDP. This is consistent with the results from the long-run test presented in table 2.

Table 3 Granger Causality results

Granger Causality test using VAR (3) using OILP, GDP, and ENG as dependent variables

	DV OILP		DV ENG		DV GDP	
	F statistics	P value	F statistics	P value	F statistics	P value
All lags of OILP	2.9233	[0.0692]*	0.2232	[0.8013]	2.6056	[0.0905]*
All lags of ENG	2.1273	[0.1368]	12.877	[0.0001]*	3.4045	[0.0465]*
All lags of GDP	2.8298	[0.0748]*	21.224	[0.3082]	78.884	[0.0000]*

5. Conclusion

There is a large literature on energy and economy wide interaction beginning from the first Energy Modeling Forum in 1977. The literature has adopted different framework in the analysis ranging from complex models to simple models. Although Bhattacharyya and Timilsina (2009) argues that a perception in the literature that complex models produce more accurate results might not ne necessarily true. A summary from the most recent research points to the fact that energy is indeed a key factor in production but yet has a disproportionate role in GDP. The divide in the literature has always being on the interpretation of the direction of causality because evidence of cointegration has become a stylized fact when the state of the art cointegration techniques are applied (Smyth & Narayan, 2015). In this paper we have attempted to pull together some of the ways in which energy might exert a significant influence on growth process. We focus on Nigeria because we know quite a lot about developed countries but less about developing countries where much is needed in energy analysis. The influence may be especially important at lower levels of development, where the overall opportunity cost of less efficient energy forms and the relative payoff to use of more efficient forms seem especially high. We utilized the ARDL BDM-test of cointegration in modeling the long run relationship between energy and economic growth along with the Toda Yamamoto approach to causality testing. Our long-run findings is consistent with (Iwayemi et al., 2010). Regarding the causality testing, we find that there is a unidirectional causality from energy consumption to economic growth. The policy implication suggests that energy conservation policies which reduce energy consumption may have an adverse impact on economic growth. Thus if we care about growth we have to be focus on not reducing energy consumption but rather focus on efficient use of energy. This finding is also consistent with the empirical evidence found by (energy growth studies grouping) example (Odhiambo (2010) for Nigeria in a panel of African countries, Tamba (2017) for Cameroon and Apergis and Tang (2013)) but not consistent with Esso (2010) for Nigeria and Zhang and Cheng (2009) Tang, Tan, and Ozturk (2016) for Vietnam.

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