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Energy, environmental pollution and industrial output nexus: the case of Nigeria

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ABSTRACT

This paper examined the impact of energy and environmental pollution on industrial output growth of the Nigerian economy. The study used per capita of gross capital formation, energy consumption, carbon emission and industrial output from 1981 to 2014. It employed Augmented Dickey Fuller for stationarity test, Engel-Granger cointegration for long-run relationship, ordinary least square for long-run estimate and diagnostic test for consistency of instruments. The findings show that all the variables except environmental pollution exert a significant positive effect on industrial output per capita growth. Specifically, it shows that environmental pollution affects the growth of the Nigerian industrial sector than the consumption of energy. In addition, it indicated that energy had greater impact on industrial output per capita. The study however, contends that government must ensure that explorative activities are carried out by adopting new technology that is capable of reducing environmental pollution.

Keywords : Energy, environmental pollution, investment, industrial growth, Nigeria.

JEL Classification : C33, C51, E22, O44, Q43.

1. Introduction

Over the past decades, energy aside capital and labour has been recognised as one of the major contributor to output growth as well as efficiency rate. Apart from this, it is also essential to all economic and human activities. Energy accessibility conditioned on its efficient availability and supply has been one of the key stones for social and economic development and welfare improvement through sustainable output growth, poverty alleviation, access to basic human welfare needs, and reliable environmental balance. Indeed, this has revealed the relative importance of crude oil for growth and welfare improvement process in the global context. Moreso, it has played significant roles in revenue generation, accumulation of foreign reserves, national savings, economic integration, infrastructure investment as well as source of energy input for industrial expansion. Aside the political density changes of host countries (Odularu, 2008); their economic and social structures have been transformed. Also, its role on industrial revolution cannot be ignored in the present world of today. According to CERA (2010), energy has been the raw material for many chemical products such as pharmaceuticals, solvents, fertilizers, pesticides, and plastics; the 16 per cent not used for energy production is converted into these other materials.

Today, energy production and exports have been identified as the foremost indicator of measuring macroeconomic activities in the world particularly for most oil-dependent nations since its emergence. Despite income accruing from oil exploration, most African countries mainly the Sub-Saharan African (SSA) countries like Nigeria have been struggling with poverty and slow economic growth for years. On the average, resource-rich countries like Africa have done even more poorly than countries without resources (Stiglitz, 2012). IMF (2008) identified factors contributing to persistent poverty as war, deficient infrastructure, poor access to capital, governance, and insufficient institutional capacity. For the last two decades, sustainable growth, job creation, and poverty alleviation have been priority development goals for Africa countries, but these goals can only be reached through implementation of broad-based socio-economic development policies that promote manufacturing and agricultural production, and health and education services delivery.

In spite of the high production of oil in Nigeria and accrued oil wealth for over three decades, there is still strong evidence of low real growth, jobless growth, non-environmental inclusive growth, deteriorated infrastructure growth, high poverty prevalence, and environmental pollution. On this note, this study examines the impact of energy and pollution on industrial output growth of the Nigerian economy between 1981 and 2014. The other part of this paper is structured into four sections; section two presents the review of past literatures and the third section shows the framework and methodology used for the study. Section four captures data presentation, analysis and discussion of findings while, the last section gave the concluding part of the study as well as policy options.

2. Literature review

Enormous literatures have been developed towards looking into the relationship between energy consumption, price and output growth since the oil shocks of the 1970s. Dargay & Gately (1994) made an exemplary work on the response of world energy and oil demand to income growth and changes in oil prices over the past decades. Response of income to oil and energy demand, they found that demand in the less developed countries (LDCs) have more responsive to income growth than the way demand in industrialized countries reacts. The LDCs exhibited much greater heterogeneity than industrialized countries in income (Dargay *et al* 1994). On the other way round, it was argued that response of the two comparisons went the other way. That is, demand in the LDCs has been less responsive to price increases but more responses to price decreases compared to industrialized countries. In industrialized countries, Dargay & Gately (1994) commented that smaller energy demand response to the price decreases of 1980's than to the price increases of the 1970's which make the distribution asymmetric. The y reported that in the LDCs, there is less evidence of demand being imperfectly price-reversible: the price reductions of the 1980's have much more of the demand reductions that followed the price increase of the 1970's compared to industrialized countries. A smaller demand response to future price increases was expected than to those of the1970s.

In 2001, Gately and Huuntington estimated the asymmetric effects of changes in price and income on energy and oil demand for 96 of the world's largest countries, in per-capita terms. Three important issues was stated to explain the study i.e. the asymmetric effects on demand of increases and decreases in oil prices; the asymmetric effects on demand of increases and decreases in income; and the different speeds of demand adjustment to changes in price and in income. They concluded that industrialized countries' energy demand responds much more to increases in oil prices than to decreases, and ignoring this asymmetric price response will bias downward the estimated response to income changes; demand's response to income decreases in many Non-OECD countries is not necessarily symmetric to its response to income increases and, ignoring this asymmetric income response will bias the estimated response to income changes; and the speed of demand adjustment is faster to changes in income than to changes in price, and ignoring this difference will bias upward the estimated response to income changes (Gately & Huuntington, 2001).

Moreover, Dargay, Gately & Huntingto (2007) employed different estimation techniques i.e. the decomposition terms to analyze the effects of price and income upon world oil demand for six groups of countries from 1971-2006. Oil products are disaggregated into two parts i.e. residual oil (used primarily for generating electricity) and other oil. They reported that most of the demand reductions since 1973-74 were due to fuel-switching away from residual oil, especially for developed countries. While, it was reported that demand for other oil has been much less price-responsive, and has grown almost as rapidly as income. Using data from 1970 to 2008, Hawaii Economic Issues (2011) found that Hawaii consumers were not very sensitive to changes in electricity prices and the price of gasoline. Energy consumption in Hawaii has not been very sensitive to the change in income either.

Under a survey analysis carried out by Cayla, Maizi & Marchand (2011), they characterized quantitatively the impact of income on household energy consumption in the French residential and transport sectors. They analyse the extent of the constraint experienced by households in terms of equipment purchasing behaviour and daily energy consumption. Their analysis shows that the least well-off households are particularly constrained since the share of their budget represented by these energy services is very large (15–25%), which corresponds to a level of energy service well below that of the better-off households. Also, they claim that households face a strong capital constraint for equipment purchases either to a large increase in the required rate of return or to a reduction in the proportion of households that are prepared to replace their equipment earlier.

On account of causality relationship, a huge literature has established different causality relations. Four testable hypotheses can be obtained from causality (Ozturk, 2010 and Payne, 2010). Using income and energy use as example: a Granger causal relationship from income to energy; a Granger causal relationship from energy to income, a feedback relationship between energy and income; and no Granger causal relationship between energy and income (neutrality). For instance, unidirectional causality from income to energy or the finding of neutrality means that energy conservation policies can take place without harming economic growth. While, unidirectional causality from energy to income or feedback between energy and income means that energy protection policies that lower energy use will lower economic growth.

Empirically, Olanrewaju (2013) opined that Nachane, Nadkarni & Karnik's research (1988) is one of the first studies that use cointegration methodology. They find long-run relationships between energy consumption and economic growth for 11 developing countries and five developed countries using the Engle-Granger cointegrating approach. Unlike the granger test, many studies employed similar methodologies but came with ambiguous results. However, different time periods and different economies also facilitated the different results. As the recent literature survey by Ozturk (2010) illustrates, no consensus neither on the existence nor on the direction of causality between the two variables of interest emerges from the past literature. As some studies find some evidence of a unidirectional causality running from energy consumption to growth (Stern, 2000; Oh & Lee, 2004; Wolde-Rufael, 2004; and Ho & Siu, 2007), others conclude on the unidirectional causality from growth to energy consumption (Mehrara, 2007; Zamani, 2007; Ang, 2008; and Zhang & Cheng, 2009) or even no causality between these variables (Halicioglu, 2009 and Payne, 2009). Also, there is evidence to support the bidirectional causality between energy consumption and growth (Glasure, 2002; and Belloumi, 2009). Mixed results are found in Soytas & Sari (2003), Lee (2006), Akinlo (2008), and Chiou-Wei, Chen & Zhu (2008) etc.

Furthermore, Mahadeven & Asafu-Adjaye (2007) found bi-directional causality for some countries while for others they found unidirectional causality running from energy consumption to economic growth; Huang, Hwang & Yang (2008) found no causality between energy consumption and economic growth in low-income groups while in middle-income and high-income countries they found that economic growth leads energy consumption; and Al-Iriani (2006) for a group of six Gulf Cooperation countries found a unidirectional causality running from economic growth to energy consumption. Past studies have shown that unidirectional causality do run from energy to GDP for panel studies like Al-Iriani (2006) and Mehrara (2007). Thus, Lutkepohl (1982) opined that their results could be affected by omitted variable bias because these studies use bi-variate models.

Considering the control variables, extensive literature has been done looking into the relationship between economic growth and trade. Scholars report granger causality between exports and GDP for Middle East and North Africa (MENA) countries (Pomponio, 1996; Xu, 1996; Al-Mawali, 2004 and Abu-Qarn & Abu-Bader, 2004). Sadorsky (2011) made a distinct work by employing panel cointegration data estimation techniques to examine the impact of trade on energy consumption in a sample of 8 Middle Eastern countries covering the period 1980 to 2007. Short-run dynamics show Granger causality from exports to energy consumption, and a bi-directional feedback relationship between imports and energy consumption. Long run elasticities estimated from FMOLS show that a 1% increase in per capita exports increases per capita energy consumption by 0.11% while a one percent increase in per capita imports increases per capita energy consumption by 0.04% (Sadorsky, 2011).

3. Theoretical framework and methodology

For the purpose of this study, the traditional neoclassical growth model is found relevant towards illustrating income and price elasticities upshot on energy consumption. It is worthwhile to note that the Solow version of the neoclassical theory indicates that the functional relationship between output and factor inputs, which can be expressed in a typical Cobb-Douglas production function as:

$$Y = f(AK, L) \quad (3.1)$$

Where Y is production output; A is technological input; K is capital; and L is labour. The capital and labour constitute the factors inputs. In a non-functional form the model assumes constant return to scale, express as:

$$Y = AK^{\alpha}L^{\beta} \tag{3.2}$$

$$\alpha + \beta = 1 \tag{3.3}$$

However, the factor intensity parameters are defined as: $\alpha = 1 - \beta$

Then, equation (3.2) can further be expressed as:

$$Y = AK^{1-\beta}L^{\beta} \tag{3.4}$$

The equation (3.4) as expressed in (3.3) indicates a constant return to scale as postulated by the classical growth model. The assumption implies output growth at an increasing rate proportional to the growth in factor inputs. The Solow model assumes that output increases at a decreasing rate as the amount of capital employed rises. A constant proportion of the existing capital stock depreciates (becomes productively useless) in each period of time.

Originally, the neoclassical growth model was designed for a closed economy – under the double assumption of constant returns to scale and exogenous technological progress (Matveenko & Korolev, 2011). Inter-country trade was not modelled as an important factor for output growth. However, once increasing returns are introduced, the scale effects of international trade become crucial in the explanation of growth. Solow notes in his keynote address that, despite a few important contributions (especially Helpman and Krugman 1985, and Grossman and Helpman 1991, Jones and Scrimgeour, 2004, 2008, Korolev and Matveenko, 2006, Matveenko, 2006), *open-economy growth theory has not attracted wide attention*.

Convergence of levels of income per head is explained with the standard neoclassical model by common technology, savings rate and population growth. When a technological laggard gets access to the more advanced technology, a fast rate of growth is possible until the steady state is achieved and both countries share the same per capita income level and growth rate. Although, there are different variants of the neoclassical growth models, as there exist several assumptions. For the purpose of empirical modelling in this study, we begin with capital dynamics equation express as:

$$\dot{K}(t) = Y(t) - C(t) - \delta K(t) \tag{3.5}$$

Where C is consumption, δ is a depreciation coefficient. The functions $Y(t), K(t), C(t)$ are assumed to be differentiated and positive, $Y(t) > C(t)$.

However, from (3.4), a special Cobb-Douglas production function with constant returns to scale and factor productivity across time is considered, which can be expressed as:

$$Y(t) = A(t)K(t)^{1-\beta}L(t)^{\beta} \tag{3.6}$$

Nevertheless, the model can be augmented with energy inputs as one of the factors required for optimal production as indicated by Mandal & Madheswaran (2010). Then, incorporating energy consumption (EC) and energy pollution (EP) as inputs in model (3.4) gives,

$$Y(t) = AK(t)^{1-\beta}L(t)^{\beta}EC(t)^{\varphi}EP(t)^{\omega} \tag{3.7}$$

According to Solow growth model, the assumption that output growth is augmented with labour (L). This is fashioned along the standard Cobb-Douglas production function i.e.

$$\frac{Y}{L} = y; \frac{K}{L} = k; \frac{EC}{L} = ec; \frac{EP}{L} = ep \tag{3.8}$$

Then, incorporating expression equation (3.8) into (3.7) gives:

$$Iny_t = a_0 + \beta Ink_t + \varphi Inec_t + \omega Inep_t \quad (3.9)$$

Finally, to control the fact that capital per capita, energy consumption per capita and environmental pollution per capita have great effect on industrial output per capita, exogenous factors (control variables) are incorporated in the model (3.9) as:

$$Iniy_t = a_0 + \beta Ink_t + \varphi Inec_t + \omega Inep_t + \rho X_t \quad (3.10)$$

However, following lead of literature such as Sadorsky (2011), trade (i.e. export and import) per capita as a measure of globalization is considered as a control factor. Therefore, the empirical model for this study is specified as:

$$Iniy_t = a_0 + \beta Ink_t + \varphi Inec_t + \omega Inep_t + \rho In\, tr_t + \mu_t \quad (3.11)$$

Where tr is total trade per capita; μ is the idiosyncratic term or stochastic term; and t is time. The A'priori expected sign for the coefficient of all the variables income is positive. As capital and energy consumption increases, more of industrial output will improve the Nigerian economy, positively. Also, energy pollution has a direct relation with industrial growth at the early stage of production.

The data for this study were obtained from secondary 1981 to 2014, particularly from World Development Index, 2014. The empirical investigation of the impact of energy consumption and environmental pollution on industrial growth in Nigeria is conducted using ordinary least square (OLS) method. In demonstrating the application of the ordinary least squared method, a multiple regression method is used with the industrial output per capita as the regressand while capital per capita, energy consumption per capita, environmental pollution per capita, and total trade per capita are the regressors.

The time series properties of the variables incorporated in multiple regression equation is examined using the Augmented Dickey-Fuller unit root test in order to determine the long-run convergence of each series to its true mean. The test involves the estimation of equations with drift and trends as proposed Dickey and Fuller (1988). The test equations are expressed as:

$$\Delta Z_t = \eta_0 + \eta_1 Z_{t-1} + \sum_{i=1}^{n} \pi_i \Delta Z_{t-i} + \nu_t \quad (3.12)$$

$$\Delta Z_t = \eta_0 + \eta_1 Z_{t-1} + \eta_1 t + \sum_{i=1}^{n} \pi_i \Delta Z_{t-i} + \nu_t \quad (3.13)$$

$$H_0 : \quad \eta_1 = 0$$

$$H_1 : \quad \eta_1 < 0$$

The time series variable is represented by Z_t and ν_t as time and residual respectively. Equation (3.12) and (3.13) are the test equation with intercept only, and linear trend respectively. Ordinary Least Square (OLS) technique is used to estimate our specified model. Diagnostic tests like Ramsey RESET test is employed for structural stability. Also, the residual diagnostic tests such as Histogram normality test, Breusch Godfrey serial correlation LM test, Breusch-Pagan-Godfrey (BPG) and ARCH Heteroskedasticity tests are also tested.

4. Data Presentation and analysis

This section presents and analyse data for the relationship among energy consumption, environmental pollution and industrial growth in Nigeria within the period of 1981 to 2014.

4.1 Unit Root Test Results

Table 4.1 presents the results of the time series properties of the variables included in the model. This pre-estimation test was carried out before estimating the long-run among energy consumption, environmental pollution and industrial growth in Nigeria.

Table 4.1 : ADF Unit Root Test Results

Variable	ADF Tau Statistics		Order of Integration
	Intercept	**Linear Trend**	
k	-3.1490**(0) [-2.9542]	-4.6980*(0) [-4.2627]	0
ec	-5.7393*(0) [-3.6537]	-5.7552*(0) [-4.2733]	1
ep	-3.4726**(0) [-2.9540]	-3.6843*(2) [-3.5529]	0
tr	-3.5560**(4) [-2.9719]	-4.9321*(1) [-4.2846]	1
iy	-5.6208*(0) [-3.6537]	-3.6981**(2) [-3.5684]	1
ect_t	-3.7281*(1) [-3.5120]	-4.3621*(1) [-4.0712]	0

Note : ** significant at 1%; ** significant at 5%; *** significant at 10% Mackinnon critical values and are shown in parenthesis. The lagged numbers shown in brackets are selected using the minimum Schwarz and Akaike Information criteria.*

Source : Authors' Computation, 2015.

The Augmented Dickey Fuller (ADF) unit-root test results in growth rates presented in table 4.1 indicate that capital per capita (*k*) and environmental pollution per capita (*ep*) are stationary at difference i.e. I(0), while energy consumption per capita (*ec*), total trade per capita (*tr*) and industrial output per capita (*y*) are stationary at first difference i.e. I(1). Thus *ec*, *tr*, and *iy* are *non-mean reverting at levels and do not converge to their long-run equilibrium* until they are first differenced. Econometric literature argued that regressing a stationary series on non-stationary series has severe implications in drawing policy inference. Hence, the long-run association among the series based on generated residual [ect_t] was also determined.

Following the Engle-Granger cointegration procedure, the generated residual or error correction term (*ect*) confirmed the existence of long-run relationship among energy consumption, environmental pollution and industrial growth that the null hypothesis at level is rejected.

4.2 Long-Run Estimates

Table 4.2 reported that capital per capita (*k*), energy consumption per capita (*ec*), and total trade per capita (*tr*) exert positive influence on industrial output growth measured by industrial output per capita in Nigeria between a period of two decades after Nigeria's independence and 2014 fiscal year and all the effects conform with the theoretical expectation. This implies that for a 10 unit increase capital per capita (*k*), energy consumption per capita (*ec*), and total trade per capita (*tr*); the Nigerian industrial output growth grow by 106.5, 8.9, and 0.86 units respectively.

However, the result indicated that environmental pollution per capita (*ep*) has negative impact on industrial output per capita. In term of magnitude, it was reported an increase of 10,000 deteriorate the value of the Nigerian industrial by 136.2 units.

Table 4.2 : Estimated Long-Run Model Results and Diagnostic Test

Dependent Variable: i*y*			
Method: Least Squares			**Observation (n) = 34**
Variable	**Coefficient**	**Std. Error**	**Prob.**
C	-6951.463	2026.577	0.0018
EC	10.6471	2.9121	0.0010
EP	-136183.1	53080.69	0.0157
K	0.8878	0.2323	0.0006
TR	0.0864	0.1349	0.5270
R-squared	0.89213	**Durbin-Watson stat**	1.4815
Adjusted R^2	0.87725	**F-statistic**	59.959
S.E. of regression	305.353	**Prob(F-statistic)**	0.0000
Residual Normality Test			
Jarque-Bera	3.4167	**Prob(J.B)**	0.1812
Breusch-Godfrey Serial Correlation LM Test			
F-statistic	14.5168	**Prob. F(2, 27)**	0.0001
Obs*R-squared	17.6170	**Prob. Chi-Square(2)**	0.0001
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.2013	**Prob. F(4,29)**	0.1871
Obs*R-squared	4.2117	**Prob. Chi-Square(4)**	0.1913

Source : Authors' Computation (2015).

In assessing the partial significance of the estimated parameters for all the incorporated industrial growth and macroeconomic indicators, result shows that all the variables except total trade per capita were found to be partially statistically significant at 5% critical level, as presented in Table 4.2.

The F-statistic result shows that all the incorporated industrial output growth and macroeconomic indicators are simult aneously significant at 5% critical level. Also, the adjusted R-squared result reveals that 68.5% of the total variation in industrial output per capita is accounted by changes in capital per capita (*k*), environmental pollution per capita (*ep*), energy consumption per capita (*ec*), and total trade per capita (*tr*) for reviewed periods. The Durbin-Watson test result reveals that there is presence of semi-strong positive serial correlation among the residuals, because of the d-value (1.482) is far from zero but close to two.

However, the result of the Breusch-Godfrey serial correlation test shows that the null hypothesis *"no serial correlation"* can be rejected at 5% significance level. Contrary, the null hypothesis of "no hetezroskedasticity" cannot be rejected at 5% significance level with the Breusch-Pagan-Godfrey heteroskedasticity test. Furthermore, the probability value of the Jarque-Bera statistic (0.1812) shows that the estimated residual series is normally distributed with zero mean and constant variance. This tends to improve the reliability of the estimated parameters and thus, necessitates other residual diagnostic test such as higher-order serial correlation and heteroskedasticity tests.

Table 4.3 shows that there is no multi-collinearity among the explanatory variables incorporated because all their centered Variance Inflation Factor (VIF) are lower than 10.

Table 4.3 : Variance Inflation Factors
Date: 08/12/15 Time: 10:48
Sample: 1981 2014
Included observations: 34

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	4107014.	1497.612	NA
EC	8.480406	1579.906	3.796125
EP	2.82E+09	7.776655	1.938636
K	0.053969	8.915474	5.395505
TR	0.018184	20.40565	8.370370

Source : Authors' computation (2015).

5. Conclusion and policy options

This study examines the relationship among energy, environmental pollution and industrial output in the Nigerian economy between 1981 and 2014. Augmented Dickey-Fuller test, Engel Granger cointegration test, Ordinary Least Square test and different post-diagnostic test are used to study the impact of energy and environmental pollution on the Nigerian industrial growth. The Augmented Dickey-Fuller test shows that the stationary level of our data varies, but the cointegration test using the Engel Granger indicated that there is long-run relationship among the per capita gross capital formation, energy consumption, carbon emission and industrial output.

The findings indicated that all the variables except for environmental pollution measured by carbon emission exerted positive influence on industrial output growth. The result indicated that environmental pollution affects the growth of the Nigerian industrial sector than consumption of energy. In addition, it indicated that energy had greater impact on industrial output per capita. However, the findings of this study show that this issue still deserves further attention in future research as Nigerian economy continue to grow with the concern for environmental degradation. Nonetheless, the depletion of energy resource due to its non-renewable nature is surely happening but the extinction is an uncertainty. As economies still benefit more from fossil fuel consumption in terms of commercialization and economic use, the exploration for new oil wells will continue to be harnessed. Government need to ensure that explorative activities are carried out by adopting new technology that is capable of reducing environmental pollution. Thus, the Nigerian industry development will be influenced adopting the global technological and innovation advancement.

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