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Section A: Environmental Science

Research Article

# Demographic Variables, Energy Intensity, Environmental Degradation and Economic Growth Nexus in the Nigerian Economy

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**Abstract:** This study examines the long run nexus as well as the causal relationships linking $CO_2$ emissions, population growth, urbanization, energy intensity and economic growth in Nigeria over the period of 1971-2011, within a multivariate framework. Cointegration technique, Vector error correction model (VECM) and VECM-based granger causality were used to examine these relationships. The cointegration results indicate that the variables have a long run equilibrium relationship. Results from the VECM estimation reveals that all the variables are positively related to environmental degradation and are statistically significant.The VECM granger causality analysis indicates a uni-directional causality running from all the variables to carbon emissions; urban population to energy intensity; population to energy intensity and a feedback effect between energy intensity and economic growth. The study opens up a new policy insight to control the environment by using energy efficient technologies.Access to alternative and affordable renewable energy systems and cleaner fuels can also play a pivotal role in improving environmental quality.

**Key Words:** Carbon dioxide emissions, Economic growth, Energy intensity, urban population, Population growth, Nigeria

## 1. INTRODUCTION

Global warming has been described as one of the most important environmental problems ravaging the human community. The ever increasing amount of carbon dioxide ($CO_2$) in the atmosphere, the dominant contributor to the greenhouse effect, seems to be aggravating this phenomenon. Environmental changes in the global community resulting from $CO_2$ emissions may be driven by many factors including economic growth, population growth, urbanization, rising energy use and transportation. Studies have shown that anthropogenic contributions to $CO_2$ emissions stem mainly from fossil fuel consumption and industrial production and these emissions have been increasing dramatically since the beginning of the Industrial Revolution [1-4]. Apart from increased fossil fuel use in industries, one of the major causes of environmental degradation in Nigeria could be attributed to rapid growth of population and urbanisation which are adversely affecting the natural resources and environment.

A larger population could result in increased demand for energy for power generation, industrial production, and transportation services, hence - increasing $CO_2$ emissions. Moreover, population growth could contribute to greenhouse gas emissions through its effect on deforestation. An increase in population causes greater deforestation, land use changes and more consumption of wood for fuel; thus, larger population raises $CO_2$ emission and contributes to the greenhouse effect [5]. On the other hand, high rates of economic activity are associated with rapid rates of energy use and waste production. [2, 6-9]. The growing population, economic expansion and the environmental deterioration face the challenge of sustained development without environmental damage. In other words, as economic activities increase as a result of increased power availability, environmental quality, on the other hand, is threatened. This scenario, therefore, calls for an understanding of the interplay among demographic variables, energy intensity, economic growth and environmental degradation in Nigeria. Outcome of such a study will help to chart a new policy direction that supports economic growth without compromising the environment.

The impacts of variables such as economic growth, population growth, urbanization, rising energy use and transportation on environment degradation have been extensively reported in the literature. However, the empirical evidence remains controversial and ambiguous to date. Whether continued increase in these variables brings greater harm to the environment is critical for the design of development strategies in both developing, emerging and even developed economies.

Martínez-Zarzoso and Maruotti[10] investigated the impact of urbanization on $CO_2$ emissions in developing countries from 1975 to 2003. Their study examined the impact of urbanization, taking into account dynamics and the presence of heterogeneity in the sample of countries. The results showed an inverted-U shaped relationship between urbanization and $CO_2$ emissions.

Li[11] used a distance function approach to examine the sources of change in carbon dioxide ($CO_2$) emissions. It evaluated the relative contributions of the sources to emission abatement using a new empirical approach. The method used the data envelopment analysis (DEA) technique to decompose emission change into seven components. The method accounts for factors that increase $CO_2$ emissions, as well as decrease them. With the application of decomposing change in China's $CO_2$ emissions at the provincial level between the years 1991 and 2006, the study found that GDP scale effect accounts for the majority of emission increments; the emission index associated with capital is a dominant contributor to emission abatement; and the effects of technical change in production and change in the GDP composition by sector played positive roles in reducing emissions.

Feng *et al.*[12] in their work titled "Lifestyles, technology and $CO_2$ emissions in China: A regional comparative analysis" used the *IPAT* model (where *I* = Impact representing $CO_2$ emissions, *P* = Population, *A* = Affluence, and *T* = emission intensity) to investigate how these main drivers contributed to the growth of $CO_2$ emissions over the period of 1949 to 2002. Through comparative analysis of the development of five regions in China, they traced lifestyle changes in China over this period. They found that household consumption across the five regions follows similar patterns, driven by changes in income and the increasing availability of goods and services. They also found that technological improvements failed to fully compensate for the increase of emissions due to population growth and increasing wealth, which is also in line with results from other studies.

Diakoulaki and Mandaraka[13] utilized the refined Laspeyres model to determine the impact of 5 explanatory factors: output, energy intensity, structure, fuel mix and utility mix on 14 EU industrial $CO_2$ emissions over the period of 1990-2003 .The analysis used two time intervals to assess progress prior to and following the agreement on the Kyoto Protocol. It is found that most EU countries made a considerable but not always sufficient decoupling effort, while no significant acceleration is observed in the post-Kyoto period.

Puliafito *et al.*[14] in their article titled "Modeling population dynamics and economic growth as competing species: An application to $CO_2$ global emissions" investigated the changes of population, gross domestic product, primary energy consumption and carbon emissions, modeled as competing species as in Lotka–Volterra prey–predator relations. The estimated results for the temporal evolution of world population, gross domestic product, primary energy consumption and carbon emissions are calculated from year 1850 to year 2150. The calculated scenarios are in good agreement with common world data and projections for the next 100 years.

Viguier[15] used four-factor LMDI decomposition for the periods 1980–90 and 1990–94 for six countries (France, Hungary, Poland, the former Soviet Union, the United Kingdom, and the United States). The study covered emissions of $NO_x$ (nitrogen oxides) and $SO_2$ (sulfur dioxide) as well as $CO_2$. The reduction of emission intensity in western countries was accompanied by a reduction in energy intensity, while in the other countries, the energy intensity rose. However, changes in fuel mix, especially in the Russian federation, provided some offset to the increase in energy intensity.

Though some Nigerian authors have carried out research on the energy-environment- growth linkage in Nigeria, most of these studies centered on energy- environment – trade-growth linkage while some mainly focus on testing the validity of the so-called Environmental Kuznet's Curve and do not consider investigating the effects of population, urbanization and energy intensity on environmental degradation in Nigeria [3,4],[16--21]. This paper is therefore an attempt to fill the research lacuna.

## 2. MATERIALS AND METHODS

**2.1 Data Measurement and Sources:** This study examines the relationship among population growth, urban population growth, energy intensity, carbon dioxide emissions and economic growth in the Nigerian economy using annual time series data for the periods 1971-2011. Data on economic growth(measured by GDP) population growth and urban population growth (measured in millions) as well as energy intensity (measured as ratio of energy consumption to GDP) are obtained from the Central Bank of Nigeria (CBN) Statistical Bulletin 2007 and 2009 edition. Data on carbon dioxide emissions (measured in million metric tons) is obtained from Carbon Dioxide Information Analysis Center, USA .All variables are transformed into logarithm form.

**2.2 Method of Analysis:** To examine the short run and the long run relationship between the variables this study utilized the co-integration and Vector Error-Correction Methodology (VECM). The cointegration approach provides information about the long run relationship between the variables while the Vector Error-Correction Method (VECM) provides information about the short-run relationship between the variables. The error correction term provides information on the speed of adjustment from the short run disequilibrium to the long run equilibrium in the event of any deviations from the long run equilibrium.

**2.3 Model Specification:** To examine the relationship between the variables, this study adopted the framework proposed by Alam *et al*[22]. The model is expressed as:

$$InCO2_t = f\{In(EI_t, GDP_t, URBN_t, GPOP_t)\} \quad \ldots\ldots(1)$$

Where: **CO2** = $CO_2$ emissions; **EI** =the intensity of energy use; **GGDP** = the gross domestic product growth rate; **URBN** = urban population, and **GPOP** = growth of population and "t" refers to current time. Linearizing equation (1), we obtain:

$$InCO2_t = \alpha_0 + \alpha_1 In\, EI_t + \alpha_2 InGGDP_t + \alpha_3 InURBN_t + \alpha_4 InGPOP + \varepsilon_t \quad \ldots\ldots (2)$$

$\alpha_0$, is intercept, $\alpha_1$ to $\alpha_4$ are the slope of the coefficients of the independent variables to be determined where $\varepsilon_t$ is the error term at time t.

**2.4 Cointegration Test:** The Johansen cointegration procedure is utilized to examine the longrun relationship between the variables[23,24].The procedure involves the estimation of a Vector Error Correction Model (VECM) in order to obtain the likelihood – ratios (LR). The procedure is specified as:

$$\Delta Y_t = \theta_o + \sum_{i=1}^{k-1} \theta i \Delta Y_{t-1} + \alpha\beta' Y_{t-k} + e_t \quad \ldots\ldots (3)$$

Where $\Delta$ is the difference operator, $Y_t$ is ($In\,CO2_t$, $In\,EI_t$, $In\,GGDP_t$, $In\,URBN_t$, $In\,GPOP_t$ ), $\theta_0$ represents the intercept, and e represents the vector of white noise process. The Matrix $\beta$ consists of r ($r \leq n - n$) cointegrating vectors. Similarly, the matrix $\alpha$ contains the error correction parameters The Johansen cointegration technique produces two likelihood ratio test statistics namely the trace test and the maximum Eigen value ($\lambda_{max}$) test. The number of significant non-zero Eigen values determines the number of cointegrating vectors in the system.

**2.5 Causality Test:** The causal relationship among the variables is examined with the help of a Granger - causality procedure based on VECM in the cases where the series are cointegrated. According to Granger's theorem when the variables are cointegrated, the simple granger causality is augmented with the Error Correction Term (ECT), derived from the residuals of the appropriate cointegration relationship to test for causality [25]. The VECM representation is as follows:

$$\Delta InCO_{2t} = \eta_1 + \sum_{i=1}^{p} \beta_{1i} \Delta InEI_{t-1} + \sum_{i=1}^{p} \kappa_{1i} \Delta InCO_{2t-1} + \sum_{i=1}^{p} \varpi_{1i} \Delta InURBN_{t-1}$$

$$+\sum_{i=1}^{p}\Psi_{1i}\Delta InGPOP_{t-1}+\sum_{i=1}^{p}\varphi_{1i}\Delta InGGDP_{t-1}+\alpha_{1}\mathrm{ECM}_{1t-1}$$
$$+\mu_{t} \quad \ldots\ldots(4)$$

$$\Delta InEI_{t}=\eta_{2}+\sum_{i=1}^{p}\beta_{2i}\Delta InEI_{t-1}+\sum_{i=1}^{p}\kappa_{2i}\Delta InCO_{2t-1}+\sum_{i=1}^{p}\varpi_{2i}\Delta InURBN_{t-1}\quad+\sum_{i=1}^{p}\Psi_{1i}\Delta InGPOP_{t-1}$$

$$+\sum_{i=1}^{p}\varphi_{2i}\Delta InGGDP_{t-1}+\alpha_{2}\mathrm{ECM}_{2t-1}\ \mu_{t} \quad \ldots\ldots(5)$$

The sign $\Delta$ is the first-difference operator and $\alpha$ is the adjustment coefficient. $ECT_{t-1}$ expresses the error correction term of the equations; the optimum lag length $p$ is selected based on the Schwarz-Bayesian information criteria (SBC) or Akaike Information Criteria (AIC); $_t$'s are the independently and normally distributed error terms with zero mean and constant variance, while $t$ denotes the time period. In equation (5), the energy variables granger causes carbon emissions if their coefficients and $\alpha$ are significantly different from zero. $F$-statistic is used to test the joint null hypothesis that the coefficients are equal to zero, and $t$-test is employed to estimate the significance of the error correction coefficient. It is important to note that a significant error correction coefficient indicates causality in the long run. Other tests for causality using other variables as the dependent can also be carried out using similar procedures.

## 3. RESULTS AND DISCUSSION

**3.1 Unit Root Test:** The empirical analysis in this study commenced by testing the properties of the variables using the Augmented Dickey-Fuller (ADF) and Philip-Perron (PP) tests.

The purpose of the test is to avoid spurious regression which may result from the regression of two or more non-stationary series. The result of the Unit Root test is presented in **Table 1**. The ADF and PP test indicate that the variables; $CO_2$ emission ($InCO_2$), Economic growth (InGGDP) and Energy intensity (InEI) are integrated of order one, I(1) while urban population growth (InURBN) and population growth (InGPOP) are integrated of order two, I (2). For the purpose of this study, we shall introduce each variable in its level of difference into our model inorder to achieve a near efficient and unbiased estimate.

**Table 1:** ADF and Phillips- Peron Unit Root Test Results

| **Augmented Dickey-Fuller (ADF) Test** | | | | **Phillip-Perron (PP) Test** | | |
|---|---|---|---|---|---|---|
| **Variables** | Level | 1st/2nd Difference | Status | Level | 1st/2nd Difference | Status |
| **InURBN** | -0.1659 | -2.9611** | I(2) | 23.2996 | -3.2894** | I(2) |
| **InPOP** | 0.9448 | -2.7230** | I(2) | 29.4324 | -3.8732** | I(2) |
| **InCO2** | 1.4922 | -5.5632** | I(1) | 2.9488 | -5.9329** | I(1) |
| **InGDP** | 1.7655 | -4.1005** | I(1) | 2.3357 | -5.2116** | I(1) |
| **InEI** | 0.3894 | -4.3410** | I(1) | 0.4897 | -7.5004** | I(1) |

**Notes: ** denote significant level at 1%.**

**3.2 Result of Cointegration Test:** Having found that the variables are integrated, the next step was totest for cointegration using Johansen's cointegration procedure. The result of cointegration test is presented in **Table 2.**

**Table 2:** Summary of the Co-integration Estimates

| Null | Alternative | $\lambda$ max test (maximum eigen value test) | $\lambda$ max(0.95) critical value | Trace Test | Trace (0.95) critical value |
|---|---|---|---|---|---|
| r = 0 | r = 1 | 63.34611** | 42.18935 | 99.8870** | 53.17660 |
| r ≤ 1 | r = 2 | 31.39978 | 38.99165 | 36.20027 | 41.66741 |
| r ≤ 2 | r = 3 | 19.36560 | 25.36211 | 30.00231 | 36.33751 |
| r ≤ 3 | r = 4 | 9.22537 | 18.99371 | 12.39790 | 19.96241 |

**** indicate significance level at 5%**

The results of the cointegration tests indicate that the maximal Trace Statistics is 99.89 which is greater than the 95 per cent critical value of 53.18. On the other hand, the $\lambda$ max statistics of 63.35 is greater than the critical value of 42.19.Hence only the null hypothesis of r=0 is rejected at the 5 per cent level of significance, suggesting the presence of a unique cointegration among the variables. This result suggests the existence of longrun relationship among the variables.

### 3.2 Results of Vector Error Correction Model

**Table 3.1:** Parsimonious coefficient estimates of error correction models

| **Variables** | **D(lnCO2)** | **Std.error** | **t-value** |
|---|---|---|---|
| Error Correction (ECM) | -0.628871 | 0.25974 | -2.42110** |
| D(InEI(-1)) | 0.565449 | 0.52192 | 1.08341* |
| D(InGDP(-1)) | 1.25887 | 0.29080 | 4.32893*** |
| D(InPOP(-1),2) | 0.92297 | 0.40167 | 2.29784** |
| D(InURBN(-1),2) | 0.51152 | 0.08856 | 5.77621*** |
| Adj. $R^2$: 0.5911;<br>S.E equation: 0.3023;<br>Log likelihood: 2.3894;<br>Schwarz SC:0.9134 ; | Sum sq. resides: 1.6112;<br>F-statistic: 5.0015;<br>Akaike AIC: 0.4862;<br>Mean dependent: 0.321663 | | |

*****, **, and* indicate significance levels at 1%, 5% and 10% respectively.**

The parsimonious VECM which captures the short run properties of the variables is presented in **Table 3.1**. It shows that the estimated ECM is a good fit (F = 5.0015) and the good log –likelihood value (2.3894) and the Akaike information Criteria (0.4862) further corroborate the appropriateness of the model. This shows that $CO_2$ emission in Nigeria is responsive to changes in economic growth, population growth, urban population growth and energy intensity. It also implies that economic growth, energy intensity, population growth and urban population growth are some of the key determinants of $CO_2$ emission growth in Nigeria.

Apart from the reported diagnostic tests above, the error correction term is rightly signed (negative) as theory has predicted. The VEC term captures the adjustment from the short to long-run equilibrium in

$CO_2$ emission growth. The VEC coefficient of -0.63 (which is also very significant) indicates a rapid contemporaneous adjustment in $CO_2$ emissions in the short run to its long-run position.

### 3.3 Results of Causality Test

**Table 3.2:** The Result of Causality Test

| **NULL HYPOTHESES** | **SOURCE OF CAUSATION** | | | | | |
|---|---|---|---|---|---|---|
| | **SHORTRUN** | | | | | **LONGRUN** |
| | **InCO2** (F-stats) | **InGPOP** (F-stats) | **InURBN** (F-stats) | **InEI** (F-stats) | **InGGDP** (F-stats) | **$ECT_{t-1}$** (t-stats) |
| InGPOP does not Cause InCO2 | | 2.7615* | | | | 3.7566*** |
| InURBN does not Cause InCO2 | | | 1.8344 | | | 6.1102*** |
| InEI does not Cause InCO2 | | | | 3.15004** | | 2.2039** |
| InGDP does not Cause InCO2 | | | | | 5.2267*** | 4.1358*** |
| InGPOP does not Cause InEI | | 3.9976** | | | | 4.3782*** |
| InURBN does not Cause InEI | | | 1.3653 | | | 2.2027** |
| InGGDP does not Cause InEI | | | | | 1.7732 | 3.9673*** |
| InEI does not Cause InGGDP | | | | 2.8963* | | 2.4762** |

**Notes: ***, ** and * denote significant levels at 1%, 5% and 10% respectively**

The result for the VECM-based granger causality test is presented in table 3.2. The Akaike Information Criterion was used in determining the lag length selection. The results from the table indicate a bi-directional causality between energy intensity and economic growth in the long run indicating that Nigeria is an energy intensive economy. In other words, increased energy use induces changes in the commercial sector where energy has been used as basic input while expansion in economic activities influences changes in energy consumption.

The granger causality analysis also indicates a uni-directional causality running from all the variables (InGGdp, lnEI, lnGPoP, lnUrbn) to carbon emissions; urban population to energy intensity and population to energy intensity. Increased economic growth induces greater use of natural resources and also causes increased undesirable activities that generate pollutants that destroy the environment. With increasing population, demand for agricultural land, natural resources, water resources etc are increased, leading to destruction of forests, pastures, fertile agricultural land and environmental pollution and resulting in increased $CO_2$ emissions. Urban population granger causes $CO_2$ emissions because with increasing urbanization, the use of infrastructure, transportation services and energy increases and so transition from agriculture to industry will also increase pollution of the environment. This also implies that energy consumption in Nigeria encourages the use of dirty fuels that promotes $CO_2$ emissions and the introduction of low carbon emission technologies and reducing the consumption of high carbon emitting fuels are viable options that can help reduce carbon dioxide emissions.

## 4. CONCLUSION AND POLICY IMPLICATIONS

Applying the cointegration technique and Vector error correction model (VECM), this study investigated the dynamic linkages among $CO_2$ emissions, population growth, urbanization, energy intensity and economic growth for Nigeria during the period 1971–2011 in a multivariate framework. The result suggests that there exists robust long-run relationship among the variables. The VECM - based granger causality results revealed that increased economic growth, urban population and population growth lead to greater use of natural resources and also cause increased undesirable outputs and pollutants that are detrimental to the environment. The results also indicate that energy intensity in Nigeria resulted in environmental degradation due to extensive use of high carbon emitting fuels.

A shift in policy framework that emphasizes the utilization of energy efficient technologies will reduce the adverse effects of energy use on the environment. Moreover, access to alternative and affordable renewable energy systems and cleaner fuels can also play a pivotal role in improving environmental quality.

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