Int. Journal of Economics and Management 10(1): 173 – 187 (2016)

PERTANIKA JOURNALS

IJEM

International Journal of Economics and Management

Journal homepage: http://www.econ.upm.edu.my/ijem

Emissions From Agricultural Sector and Financial Development in Nigeria: An Empirical Study

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ABSTRACT

The present paper investigates the impact of financial development on carbon dioxide (CO_2) emissions from the agricultural sector in Nigeria. In an agricultural dependent economy such as Nigeria, the nation depends on the agriculture sector to feed its growing population and to foster economic development. However, in this study, we consider CO_2 emission from the agriculture sector to be the indicator for the environmental quality. We posit that like any other developing economy, there is a role play by the financial sector to promote growth and progress in enhancing economic development. The pursuit for economic development will ultimately result in environmental pollution. We employ the Autoregressive Distributed Lag (*ARDL*) approach on annual data spanning from 1971-2011. The control variables included in this study comprises national income, energy consumption, foreign direct investment and population. Our results suggest that all variables exhibit long-run relationship with CO_2 emissions from the agricultural sector. Financial development and national income show negative relationship with CO_2 emissions from agricultural sector, suggesting that economic development has not taken place at the expense of CO_2 emissions. However, the increase in population and foreign direct investment has led to an increase in CO_2 emissions from the agricultural sector.

JEL Classification: G21, Q43, Q53

Keywords: Carbon emissions, Energy consumption, Financial development, *ARDL*, Nigeria

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INTRODUCTION

In April 2014, Food and Agriculture Organization (FAO) of the United Nations estimated that the greenhouse gas emissions from agriculture, forestry and fisheries have almost doubled over the past five decades and could increase by an additional 30% in the next four decades. Agricultural related emissions from crop and livestock production grew from 4.7 billion tons of carbon dioxide equivalents in 2001 to over 5.3 billion tones in 2011, representing a 14% increase. The increase occurred mainly in the developing countries due to an expansion of total agricultural outputs (FAO, 2014). The Nigeria's agricultural sector is made up of four main activities namely; crop production, livestock, forestry and fishing. Crop production accounted for 83.9% of the overall growth of the agricultural sector and the largest contributor to real Gross Domestic Product (GDP), registering 18.6% of total real GDP in the second quarter of 2014. The contribution of the agricultural sector to GDP was 17.1%, 17.9%, 23.8% and 22.1% in the first, second, third and fourth quarter of 2014, respectively (National Bureau of Statistics, 2015). As such agricultural sector may be responsible for producing carbon emissions in Nigeria.

The negative effect of carbon emissions from agriculture and fossil fuel and the accumulation of greenhouse gases on earth's surface have posed challenges across all nations in the world, irrespective of who is responsible for the greenhouse gases accumulation. The earthquake in Haiti, the outburst of flood in Pakistan and Australia, the tsunami in Japan and the wild fire in Russia are among the major disasters observed in recent past which may be the consequences of environmental degradation. These scenarios have resulted in damages to the natural resources like forest and wild life, agricultural land and output, infrastructures and most importantly to human lives. Environmental experts and economists have considered these disastrous events as a major source of disturbances to economic growth and financial development which significantly impacted the environment (Shahbaz *et al*., 2013).

Most economies will desire to strive for environmentally sustainable financial activities. However, growth in economic activities will lead to the increase in energy consumption, which in return foster the combustion of fossil fuel and subsequently increase carbon dioxide (CO_2) emissions, a toxic substance that increases greenhouse gas and global warming. The danger and the consequences of global warming and climate change have led to the establishment of environmental friendly advocacy organizations. These organizations have greatly contributed to the global green movement by facilitating the conditions under which human and natural environment can come together to satisfy the economic and environmental needs of societies. Among others, these organizations include Kyoto Protocol, Environmental Protection Agency, Greenpeace and Nature Conservancy among others. As a result of the importance to ensure quality environment, the European Union for example has incorporated measure to prevent greenhouse gases emissions up to 40% from 2008-2012 as a requirement to join their organization (Apak and Atay, 2013).

In the case of Nigeria, report from the World Bank in 2007 revealed that Nigeria accounted for nearly one-sixth of the global gas flaring which emitted 400 million tons of carbon dioxide into the atmosphere. This mostly has contributed to the rise in sea level at tropical coast in southern part of the country (Habil, 2007) with potential tendency to shrink fertile soil and water. Parallel with the effort to reduce CO_2 emissions, European Commission donated €27 million of financial support on 4th July 2013 to help improve the renewable energy policy in Nigeria. The reduction of CO_2 emission is necessary to achieve the required target of food production that will feed about 170 million population in Nigeria, and consequently, a specialize bank called Nigeria Agricultural Cooperative and Rural Development Bank was established to provide credit facility to farmers and small scale businesses. Unfortunately, the availability of credit facilities to farmers not only accelerate the tendency of farmers to purchase energy emitting farm implements like machines and equipment, but it could also indirectly escalate energy emissions.

Hence, while financial development is seen as an alternative way in achieving quality environment, the challenge remains as CO_2 emission is related to energy consumption that serves as the catalyst of economic growth and development. In this situation, reducing CO_2 emissions would invariably implies slowing down economic growth, for which the country will not be passionate to adhere to. This calls for innovative solutions through which the dual objectives of greater economic growth and sustainable environment could be achieved. As noted by Shahbaz *et al*. (2013) this problem has persisted since the 1960s, as there has been an upsurge of awareness on environmental degradation and its increasingly harmful effects on the environment and climate change by the policy makers, environmental activists, and economists both at the local and global levels. Many economies have subsequently proposed rules and regulatory policies to address environmental pollution and degradation in the pursuit of economic development.

The present paper investigates the relationship between financial development and CO_2 emissions from agricultural sector in Nigeria for the period 1971-2011. There are few studies on CO_2 emission from agriculture as an indicator of environmental quality and its relation to financial development. The scarcity of such research allows this study to fill in the gap and contributes to the growing literature.

The paper is organized as follows. In the next section, the related literature linking financial development and environmental quality are reviewed, while Section 3 presents the model and method used in the analysis. Section 4 discusses the empirical results, and finally, the last section concludes the paper by iterating and highlighting the key findings of the study.

LITERATURE REVIEW

Literature that link financial development and carbon emissions for environmental quality is less common for the case of Nigeria. However, Bello and Abimbola (2010) investigated the EKC hypothesis for the case of Nigeria and revealed evidence of insignificant relationship between financial development and environmental quality. This could be the result of using capital market indicators as a proxy for financial development. On contrary, this study uses a better representation of financial development which includes the money market indicator. The money market indicator is a better representative of the financial activities in developing countries, in particular Nigeria. This is consistent with the findings of Singh (1997) which suggests that capital market indicator such as market turnover, market capitalization and numbers of listed companies among others are reflected by gambling and casinos in developing countries owing to lesser capital market development in those countries.

However, the seminal work of Grossman and Krueger (1991) deduced inference from the work of Kuznets (1955) and extended it to incorporate environmental pollution and climate change by relating income per capita or the level of economic development with environmental performance. In line with Kuznets (1955), the findings of Grossman and Krueger (1991) revealed that the relationship between economic growth and environmental quality is non-linear or depicting an inverted U-shape, suggesting that the initial stage of economic growth is associated with greater environmental pollution until a turning point is reached and thereafter, additional expansion of output level improves environmental quality. Since then, several empirical works have documented how economic growth, energy consumption, foreign direct investment, trade openness and other macroeconomic variables have affected environmental quality. Most of the findings documented mixed results owing to differences in variables employed, frequency of data used and the stages of economic development of the country under consideration.

In recent years, the literature of income and environmental nexus has been extended to include the role of financial sector. This has led to the emergence of numerous studies on financial development and environmental quality nexus. Some of the studies that investigated the relationship between financial development and environmental quality along with other variables include: Bello and Abimbola (2010), Jalil and Feridun (2011), Islam *et al*. (2013), Ozturk and Acaravci (2013), Apak and Atay (2013), Shahbaz *et al*. (2013), Azhar *et al*. (2014), Boutabba (2014), and Chang (2015).

Although variable indicators, determinant of data normality in relation to the frequency and level of advancement of a country can influence the direction of outcomes, recent studies have made effort to incorporate better control variables and new indicators to reduce miss-specification and bias problems. Literature in the area which relates to the effect of financial development and output on environmental pollution and climate change seems to be divided into two main research strands. First, the argument is that financial development is closely related to economic growth and energy consumption. Second, economic growth depends heavily on energy consumption, therefore, financial development is an extension of economic growth that incorporates better innovation to handle economic activities.

In the recent studies that investigate financial development and energy consumption, Islam *et al*. (2013), Aslan *et al*. (2014), Alam *et al*. (2015) found that financial development increases energy demand. However, Chang (2015) used a panel threshold framework and found that financial development has a declining effect on energy consumption beyond a threshold for advanced economies while financial development is positively related to energy consumption for emerging economies. Similarly, literature also provides argument on the interconnectivity between financial development, income and environmental quality, but this is a more recent area particularly with respect to developing nations.

For example, on one hand, Ozturk and Acaravci (2013) found that financial development has no significant impact on environmental quality but economic growth and trade openness have significant effects in causing environmental pollution. However, on the other hand, Boutabba (2014) reveals a positive effect of financial development on environmental degradation while Jalil and Feridun (2011) and Shahbaz *et al*. (2013) provide negative evidence between financial development and CO_2 emission, suggesting that financial development has not taken place at the expense of environmental quality. Thus, these mixed results may be owing to developmental and indicator differences, among others. Some of the studies focussed on advanced economies (Çoban and Topcu, 2013) while others focus on emerging economies (Ozturk and Acaravci, 2013; Boutabba, 2014).

Thus, our study extends the frontier of knowledge and contributes to the existing body of literature by differentiating our work to include emissions from agriculture sector as proxy for environmental quality, inclusion of population and money market financial indicators in modelling the relationship between financial development and environmental quality in Nigeria.

METHODOLOGY

The theoretical foundation for this study derives its intuition from the extended production theory that considers energy consumption as an additional production input beside labour and capital. Once energy consumption is incorporated in the production function, then it is plausible to relate it directly with CO_2 emissions. The extended production theory also provides the framework to model financial development and foreign direct investment (*FDI*) as technological progress. This was argued on the basis that greater financial development and efficient *FDI* could improve productivity and economic growth. For instance, recent studies that used the extended production theory to model the relationship between financial development, energy consumption and CO_2 emissions include; Omri *et al*. (2015) and Rafindadi and Ozturk (2016). However, employing emissions from agricultural sector significantly differentiate this study with existing literature.

Furthermore, modelling the log–log model specification will provide efficient results by reducing the sharpness in time series data compared with the simple linear-linear specification (Shahbaz, 2013). Our model specification will follow existing literature which provides empirical evidence that investigates the bond between economic growth, energy consumption, financial development, *FDI* net inflows and CO_2 emissions. Other than using emission from agriculture, we have included population to further differentiate this work with previous literatures, such as the work of Wang *et al*. (2011) and particularly, Jalil and Feridum (2011), Coban and Topcu (2013), and Shahbaz *et al*. (2013) who have included financial development in their analysis.

Following these authors, the functional form for the CO_2 emissions from the agriculture sector in Nigeria can be specify as per Equation (1) below,

$$CO2_t = f\,(DC_t, X_t) \qquad (1)$$

where CO_{2t} represents emissions from the agriculture sector, DC_t is the proxy for financial development, X_t is a set of control variables namely Y_t, EC_t, PO_t *and* FDI_t which indicate economic growth, energy consumption, population and foreign direct investment net inflows respectively. Specifying Equation (1) in a stochastic form, we have the following log-log specification linking CO_2 emissions from the agriculture sector to its determinants as follows:

$$lnCO2_t = \gamma_0 + \gamma_1 \, lnY_t + \gamma_2 \, lnEC_t + \gamma_3 \, lnDC_t + \gamma_4 \, lnPO_t + \gamma_5 \, lnFDI_t + \mu_t \qquad (2)$$

Parameters γ_s' are coefficients or elasticities to be estimated, and μ_t is the stochastic error term, expected to be normally distributed with zero mean and constant variance. Equation (2) above expresses the long-run relationship between carbon emissions from agriculture (indicator of environmental quality) with its determinants - economic growth, energy consumption, financial development, population and *FDI* net inflows. It is expected a *priori* that $\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5 > 0$. However, higher level of economic development as well as higher level of financial development could mitigate CO_2 emissions then we would expect that, $\gamma_1, \gamma_3 < 0$.

In this study, we adopt the autoregressive distributed lag (*ARDL*) modelling approach to cointegration proposed by Pesaran *et al*. (2001). We employed the *ARDL* approach to establish long-run equilibrium relationship between the explanatory variables of economic growth, financial development, energy consumption, population, *FDI* net inflows and the explained variable, CO_2 emissions from agriculture. Some of the justification for using the method includes the followings: First, unlike other cointegration approaches, the *ARDL* approach could be used when variables are stationary at *I*(0), *I*(1) or combination of both. Second, it has a good property for small sample size. Third, both the short and long run parameters can be estimated simultaneously without losing much degree of freedom (Sulaiman and Abdul-Rahim, 2015). Resting on these advantages of *ARDL*, we construct the unrestricted error-correction model (UECM) to reflect the relationships of our variables as shown below, which can be used to test for cointegration – the bound F-test for cointegration:

$$\begin{aligned} \Delta lnCO2_t = \; & \varphi_0 + \sum\nolimits_{i=1}^{n} \varphi_{1i} \, \Delta lnCO2_{t-i} + \sum\nolimits_{i=0}^{n} \varphi_{2i} \, \Delta lnY_{t-i} + \sum\nolimits_{i=0}^{n} \varphi_{3i} \, \Delta lnEC_{t-i} \\ & + \sum\nolimits_{i=1}^{n} \varphi_{4i} \Delta lnDC_{t-i} + \sum\nolimits_{i=1}^{n} \varphi_{5i} \, \Delta lnPO_{t-i} + \sum\nolimits_{i=1}^{n} \varphi_{6i} \, \Delta lnFDI_{t-i} \\ & + \alpha_1 \, lnCO2_{t-1} + \alpha_2 \, lnY_{t-1} + \alpha_3 \, lnEC_{t-1} + \alpha_4 \, lnDC_{t-1} \\ & + \alpha_5 \, lnPO_{t-1} + \alpha_6 lnFDI_{t-1} + \varepsilon_t \qquad (3) \end{aligned}$$

To test for cointegration or to estimate the long run equilibrium link among the variables, we test the combine null hypothesis of no cointegration on the level variables in Equation (3), which is $H_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = 0$ against the alternative hypothesis $H_a: \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq 0$, which suggests the existence of cointegration among the variables. The presence of cointegration or otherwise is based on the outcome of F-statistics test obtain via *OLS* framework of the *UECM-ARDL* as per Equation (3). The *F*-statistics value is then compared with critical values of the table advanced by Narayan (2005), namely the lower critical bound and the upper critical bound. If the estimated *F*-statistics is greater than the upper bound value of the table based on our observation, we can reject the null hypothesis and accept the alternative hypothesis that cointegration exist. On the other hand, if estimated F-statistics is lower than the lower bound, the null hypothesis cannot be rejected and cointegration does not exist. Conversely, if the *F*-statistics falls in between the upper and lower bound, the outcome is inconclusive.

According to Pesaran *et al*. (2001), the long-run model as per Equation (2) can be derived from the following short-run *ARDL* model;

$$lnCO2_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i}\, lnCO2_{t-i} + \sum_{i=1}^{n} \beta_{2i}\, lnY_{t-i} + \sum_{i=1}^{n} \beta_{3i}\, lnEC_{t-i} + \sum_{i=1}^{n} \beta_{4i}\, \mathrm{lnDC}_{t-i} + \sum_{i=1}^{n} \beta_{4i}\, lnPO_{t-i} + \sum_{i=1}^{n} \beta_{6i}\, lnFDI_{t-i} + \epsilon_t \quad (4)$$

From Equation (4) we can have the long-run model as per Equation (2) above,

$$lnCO2_t = \gamma_0 + \gamma_1\, lnY_t + \gamma_2\, lnEC_t + \gamma_3\, lnDC_t + \gamma_4\, lnPO_t + \gamma_5\, lnFDI_t + \mu_t$$

with $\gamma_0 = \frac{\beta_0}{1-\sum\beta_{1i}}, \gamma_1 = \frac{\sum\beta_{2i}}{1-\sum\beta_{1i}}, \gamma_2 = \frac{\sum\beta_{3i}}{1-\sum\beta_{1i}}, \gamma_3 = \frac{\sum\beta_{4i}}{1-\sum\beta_{1i}}, \gamma_4 = \frac{\sum\beta_{5i}}{1-\sum\beta_{1i}}$, and $\gamma_5 = \frac{\sum\beta_{6i}}{1-\sum\beta_{1i}}$.

Using the residuals of the long-run model, we can also infer cointegration from the following short-run or error-correction model,

$$\Delta lnCO2_t = \theta_0 + \sum_{i=1}^{n}\theta_{1i}\, \Delta lnCO2_{t-i} + \theta_0 + \sum_{i=1}^{n}\theta_{2i}\, \Delta lnY_{t-i} + \sum_{i=1}^{n}\theta_{3i} \Delta lnEC_{t-i} + \sum_{i=1}^{n}\theta_{4i}\, \Delta lnDC_{t-i} + \sum_{i=1}^{n}\theta_{5i}\, \Delta lnPO\cancel{t-i} + \sum_{i=1}^{n}\theta_{6i}\, \Delta lnFDI_{t-i} + \lambda ECT_{t-1} + \eta_t \quad (5)$$

where the error-correction term, ECT_{t-1}, is the residual of the long-run model - Equation (2) lagged one period,

$$ECT_{t-1} = \mu_{t-1} = lnCO2_{t-1} - [\gamma_0 + \gamma_1\, lnY_{t-1} + \gamma_2\, lnEC_{t-1} + \gamma_3\, lnDC_{t-1} + \gamma_4\, lnPO_{t-1} + \gamma_5\, lnFDI_{t-1}] \quad (6)$$

The parameter λ is the error-correction parameter implying the speed of adjustment. The negative sign (magnitude between 0 and 1) and significant, ECT_{t-1} would imply cointegration, that is, the model exhibits long-run relationships between $lnCO2_t$ and its determinants; ln Y_t, $lnEC_t$, $lnDC_t$, $lnPO_t$ and $lnFDI_t$.

If long-run relationships exist, then unidirectional or bidirectional causality may exist among the variables. As a result, a Granger causality test employing the Vector Error Correction

Model (VECM) is used to determine the causal link among the variable. The knowledge of causal relationship among the variables could be of importance to policy maker regarding emissions control particularly from agriculture and other energy related emissions.

In line with our objectives as stated earlier, the important variables or their indicators has been incorporated in the model. These include emissions from the agriculture sector, economic growth, energy consumption, financial development, population and foreign direct investment (*FDI*) net inflows. On this ground, annual data of GDP at constant 2005 price- US dollars was collected from United Nations Statistical Division for the period of 1971-2011. Data on energy consumption per capita, domestic credit, population and *FDI* net inflows were collected from the data base of World Development Indicators for the period of 1971-2011. To further differentiate our work with previous literature, CO_2 emission from the agricultural sector obtained from the Food and Agriculture Organization of United Nations for the same period was used to capture environmental quality. Evidently, CO_2 emission from agriculture seems to have been neglected in the previous studies of financial development and environmental quality nexus.

DISCUSSIONS ON EMPIRICAL RESULTS

Although one of the advantage of using the *ARDL* approach to infer cointegration is that it does not require for each of the variable to be tested for unit root, however, it requires that variables in the series involve are not integrated of order more than *I*(1). Otherwise, the presence of *I*(2) and beyond violates the requirement of using the *ARDL* modeling approach and Pesaran *et al*. (2001) and Narayan (2005) critical values for the bounds test will be invalid. In view of this, we have conducted the unit root test using the standard Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) procedure to test for the order of integration of the series. The results of the test presented in Table 1 suggests that all variables in question passed the test that they are not *I*(2), but either they are *I*(0) or *I*(1). This justifies the adoption of *ARDL* cointegration test suggested by Pesaran *et al*. (2001).

Table 1 Results of unit root tests

Variables	ADF (level)	ADF (first-difference)	PP (level)	PP (first-difference)
ln CO2t	-0.9285	-4.1085***	-0.8748	-8.1456***
ln Yt	1.9931	-4.1172***	1.5607	-4.0938***
ln ECt	-2.9894**	-5.6612***	-3.1398**	-5.6588***
ln DCt	-2.4608	-6.0959***	-2.2896	-9.1683***
ln POt	-2.3867	-1.1522	-5.7605***	-0.8220
ln FDIt	-1.5112	-11.1737***	-2.4782	-11.0905***

Note: Asterisks *** and ** indicate 1% and 5% significant level, respectively.

To test for the existence of cointegration relationship among the variables, the unrestricted error correction model in Equation 3 was estimated to generate *F*-statistic through the OLS variable addition test. The value of *F*-statistics (4.9532) is greater than the critical values of the upper bounds (see Narayan, 2005) at 5% and 10% level of significance respectively as presented in Table 2. This suggests the existence of cointegration between all variables with carbon emissions from the agriculture sector. Therefore, we accepted our alternative hypothesis and did not fail to reject the null hypothesis of no cointegration.

Table 2 Results of ARDL bounds F-test for cointegration

Bounds test case III: Unrestricted intercept and no trend		
Estimated equation		*lnCO2t=f(lnYt,lnECt,lnDCt, lnPOt, lnFDIt)*
Optimal lag structure		(1,1,0,0,0,1)
F-statistics		4.953**
Significant level	Critical Values (T=41)	
	Lower bounds(0)	Upper Bounds(1)
1%	4.045	5.898
5%	2.962	4.338
10%	2.483	3.708

Note: *F*-statistics is greater than the upper bonds at 5% significant level, indicating cointegration among variables.

Table 3 Results of long-run and short-run models

Dependent variable= ln $CO2_t$		
Variables	Coefficients	*t*-statistics
Long-run model	(1,1,0,0,0,1)	
ln Yt	-0.4543*	-2.0296
ln ECt	0.2550	0.17734
ln DCt	-0.0934*	-1.7772
ln POt	0.8457***	3.4089
ln FDIt	0.1951***	2.8053
Constant	4.1150	0.4054
Short-run model	(1,1,0,0,0,1)	
Δln Yt	0.5877	1.5049
Δln ECt	0.1599	0.17943
Δln DCt	-0.0586	-1.5623
Δln POt	0.5303**	2.4796
Δln FDIt	0.0537	1.3108
Constant	2.5804	0.3977
ECT_{t-1}	-0.6271***	-3.7187

Note: ***, ** and * indicate 1%, 5% and 10% significant level, respectively

In view of the existence of cointegration among our variables, we proceed to estimate the long-run coefficients of the *ARDL* model and present the results in Table 3. The result of long-run coefficients were estimated after an optimal lag length (2) was selected based on

Schwarz Bayesian Criterion (SBC). The decision to choose SBC was due to its ability to select parsimonious model with the smallest possible lag length that minimizes the loss of degree of freedom. The result shows that coefficient of economic growth is significant and inversely related to emissions from agriculture at 10% level. An increase in economic growth by 10% could reduce CO_2 emissions from agricultural sector by 4.5%, suggesting that economic growth improves environmental quality. These findings support the theoretical arguments in the literature that the use of cleaner sources of energy leads to economic growth that improves environmental quality. However, the finding is in contrast to that of Halicioglu (2008) who reported a positive and significant impact of growth on CO_2 emissions.

Furthermore, the coefficient of domestic credit, which is the indicator for financial development is negative and significant at 10% level. Precisely, an increase in financial development by 10% has the capacity to reduce emissions and improve environmental quality by 0.9%. Similar to economic growth, financial development has not taken place at the expense of environment in the long-run. This result is in consonance with the result of Jalil and Feridun (2011) for China and Shahbaz *et al*. (2013) for Romania. More so, the long-run coefficient of population is positive and significantly related to emissions from the agricultural sector, indicating that increase in population by 10% could increase environmental pollution by 8.5%. This corresponds with the postulation that an expansion in population would increase land openness for residential construction, agriculture, production and other economic activities. The result is intuitive with the findings of Islam *et al*. (2013).

Again, the estimate of *FDI* net inflows in the long-run is significant and positively related to CO_2 emissions from agricultural sector. This suggests that *FDI* net inflows contribute to environmental degradation in Nigeria. However, the power of its coefficient in polluting the environment seems to exhibit lesser momentum as compared with that of population. Therefore, *FDI* net inflows have also taken place at the cost of environmental quality. This result provides support to the findings of Bello and Abimbola (2010) which conduct similar study in Nigeria. On the contrary, the long-run coefficient for energy consumption seems not to be statistically different from zero.

On the other hand, the error-correction model also supports cointegration or the long-run relationships between carbon emissions and its determinants in Nigeria. The parameter, λ, of the error-correction term, ECT_{t-1}, is negative, less than one in absolute terms and statistically significant at the 1% level as indicated in the Table 3. The coefficient (0.6271) represents the speed of adjustment in the event of disequilibrium in the short-run. It suggests a moderate speed of adjustment back to long-run equilibrium.

The coefficient of economic growth is positive but not significant and hence does not possess any statistical power to cause environmental degradation in the short-run. Similarly, the coefficient of financial development and energy consumption are negative and positive respectively but seems not to be significantly different from zero, suggesting that they possess less power to make any inference during the short-run period. However, the coefficient of population is positive and significant at 5% level, indicating that an increase in population by 10% will increase carbon emissions by 5.3%. Population is the main source of environmental pollution in the short-run. Birth rate level within the short-run in Nigeria may have played important role on the direction of this result. This result is congruent with the findings of Ahmed *et al*. (2015) who conducted similar study for Pakistan.

To enhance the reliability of our results, a diagnostic checking has been conducted and the result is presented in Table 4. The diagnostic checking passes three major tests of serial correlation, normality and heteroscedasticity. This means that the stochastic error term is white noise, normally distributed with zero mean and constant variance, hence the model is robust. To further enhance the reliability of our result, the model was diagnosed for stability tests using the cumulative sum of recursive residuals (CUSUM) and cumulative sum of square of recursive residuals (CUSUMSQ). The result suggests that the coefficients of the model are fairly stable, consistent and reliable as the results are still within the critical bound at 5% level of significance. This implies that the result can be used for policy inference. The stability test results were presented in Figures 1 and 2.

Table 4 Diagnostic tests

Test Statistics	LM Version	F Version
A: Serial correlation	(1) = 0.40298[0.526]	(1, 29)= 0.30278[0.586]
B: Functional form	(1) = 7.6534[0.006]	(1, 29)= 7.0805[0.013]
C: Normality	(2) = 0.23325[0.890]	Not applicable
D: Heteroscedasticity	(1) = 0.58172[0.446]	(1, 37)= 0.56024[0.459]

Notes: A: Lagrange multiplier test of residual serial correlation; B: Ramsey's RESET test for misspecification error; C: Jarque-Berra test for normality of residuals; and D: ARCH test for heteroscedasticity. Figures in square brackets [.] are *p*-values.

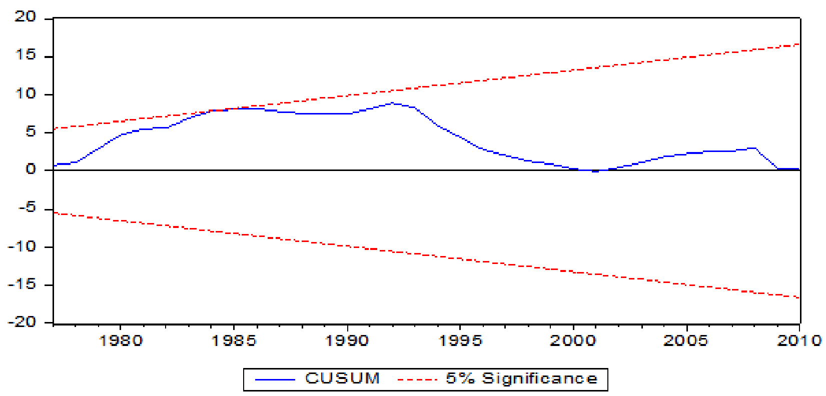

Figure 1: Plot of Cumulative Sum of Recursive Residuals

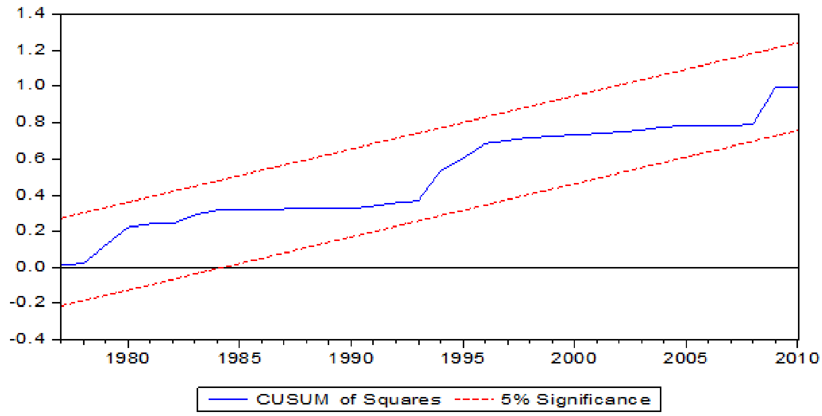

Figure 2: Plot of Cumulative Sum of Squares of Recursive Residuals

In addition, the result of the VECM Granger causality test shows that the long-run result exhibits a feedback relationship running from energy consumption to foreign direct investment net inflows and population, and a bidirectional causality between foreign direct investment net inflows and population expansion. The short-run causal relationship shows a unidirectional relationship running from population expansion to CO_2 emissions from agriculture, energy consumption and foreign direct investment net inflows. However, indicator of financial development and CO_2 emissions from agriculture appear to be independent.

Table 5 VECM *Granger* causality test

Variables	Short-run causalities:						Long-run causalities:
	Δln CO2	Δln Y	Δln EC	Δln DC	Δln FDI	Δln PO	ECTt-1
Δln CO2	-	-0.0882	-2.0929	0.0054	0.0307	4.9481	-0.2124
		(0.8356)	(0.1055)	(0.9207)	(0.3800)	(0.0729)	(0.3237)
Δln Y	0.0882	-	-0.2692	0.0045	0.0139	0.1553	-0.1285
	(0.2966)		(0.5850)	(0.8295)	(0.3081)	(0.8817)	(0.1288)
Δln EC	-0.0010	0.0527	-	0.0018	-0.0120	1.1923	-0.0667
	(0.9674)	(0.2887)		(0.7767)	(0.0052)	(0.0006)	(0.0107)
Δln DC	0.7752	0.0682	5.6303	-	0.0749	10.6014	-1.3099
	(0.3439)	(0.9661)	(0.2436)		(0.5685)	(0.2999)	(0.1116)
Δln FDI	-0.8652	-1.4737	7.7280	-0.2058	-	-24.1127	2.6271
	(0.3002)	(0.3700)	(0.1192)	(0.3259)		(0.0251)	(0.0030)
Δln PO	0.0043	0.0089	-0.0324	0.0005	-0.0004	-	-0.0084
	(0.3656)	(0.3412)	(0.2494)	(0.6501)	(0.6025)		(0.0804)

Note: *p*-values are in parentheses.

CONCLUSION

This study investigates the impact of financial development, economic growth, energy consumption, population and *FDI* net inflows on the environmental quality in Nigeria. We have distinguish our work with existing literature by incorporating emissions from agricultural sector to capture environmental safety and introduce population as an additional variable in the case of Nigeria. Autoregressive Distributed Lag (*ARDL*) bounds F-test, advanced by Pesaran *et al*. (2001) was used to test the long-run equilibrium relationship among the variables. Except for energy consumption, the coefficients of the determinants in the long-run model were all significant. Economic growth and financial development improves environmental quality, suggesting that financial development and economic growth have not taken place at the expense of the environmental quality. More so, the short-run coefficients of financial development, economic growth, energy consumption and *FDI* net inflow were not statistically significant. On the other hand, population was found to be significant and positively related to emissions from agriculture sector during the short-run period.

Based on these results, there is a need to further accelerate financial development and economic growth, since such expansion may further improves environmental quality. Since emissions are directly related to energy consumption we further recommend efficient use of energy from fossil sources so as to reduce environmental pollution. In addition, population expansion has consistently provide evidence of environmental degradation, meaning that there is an increase in land openness for agriculture, construction and other economic uses leading to more emissions in Nigeria. Thus, enlightenment campaign on effects of land degradation resulting from increasing population expansion need to be intensified.

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