

Dynamics of Industrial Production, Financial Development and Carbon Emission in Nigeria



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Abstract This study focused on the dynamic relationship among industrial production, financial development and carbon emission in Nigeria. Annual data set from 1960 to 2018 was employed. A long-run relationship was found for the variables of interest, while the (ECM) term suggested small and insignificantly 2% per year adjustment of short run to long run, which supported the short-run insignificant effects of both industrial production and financial development on carbon emission. The long-run result showed positive and significant effect of industrial production on carbon emission, while the long-run effect of financial development on carbon emission was negative and also significant. The causality results showed unidirectional causalities with causalities running from both industrial production and emission to financial development. We therefore concluded that industrial production increases emission, while financial development reduces it in Nigeria. We recommended that the industrial sector should adopt non-renewable energies in its production processes, while Nigeria's financial authorities and institutions should channel funds to projects that support low emission in order to achieve the proposed low-carbon economy.

Keywords Industrial production · Financial development · Carbon emission · ECM · Granger causality test · Nigeria

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1 Introduction

Nigeria, being the Africa's largest producer of oil and the sixth largest oil-producing country in the world, emits high amount of carbon emissions traceable to oil production from gas flaring and those generated from burning of fossil fuels from oil companies, power plants, cement factories and automobiles (Isa, 2014; Stephen, 2014). The development of the industrial sector occasioned by financial development has led to increase in energy consumption, especially fossil fuels with detrimental environmental effects (Gokmenoglu et al., 2015). Apart from air pollution caused by carbon emission, there are other climatic damages that are detrimental to human lives and sustenance. Such environmental impacts are flood, diseases, drought in some climates, less precipitation that can lead to heat or hot weather in others, reduction in soil fertility that reduces food supply and ecosystem damages, among others.

The oil and gas exploration activities in Nigeria involve the burning of large quantities of natural gas, a phenomenon referred to as gas flaring (Isa, 2014). Nigeria contributes about 13% of the gas flared globally every year as a result of a daily oil production of about an average of two million barrels per day (International Energy Agency, 2014). Cement production is another major source of carbon emissions in the country, and other sources of carbon emissions include fumes from fairly used cars, plants and small power generators, which are imported in large quantities due to inconsistent supply of electricity in the country (Stephen, 2014).

Consequently, the Environmental Performance Index (2014) of the Yale University ranked Nigeria 134 out of 178 countries with a score of 39.20%. In addition, the Energy Sustainability Index (2014) of the World Energy Council, which ranks countries in terms of their likely ability to provide sustainable energy policies ranked Nigeria 11th position in energy security; 108th position in energy equity; and 81st position in environmental sustainability out of 111 countries. The foregoing reveals that Nigeria, as a member of Organization of Petroleum Exporting Countries (OPEC), contributes to the global warming with the industrial sector as its major source. The industrial output in Nigeria consists of crude petroleum, natural gas, solid minerals, coal mining, metal ores, quarrying, mining, manufacturing oil refining and cement (Central Bank of Nigeria, CBN, 2014).

Nigeria has become the largest economy in Africa with the current recalculation of her gross domestic product (GDP) of US\$415,080 billion (equivalent to ₦130.854 trillion using the current exchange rate of ₦315.25 to \$1) (International Monetary Fund (IMF), 2016). Nigeria has now been ranked ahead large African countries like Egypt, South Africa and Algeria. The growth of Nigeria's economy is attributed to oil production as it provides over 95% of export earnings, 25% to GDP, 90% of foreign exchange earnings and about 90% of government revenues (IMF, 2012). In the same vein, oil production has been identified as one of the major sources of carbon emission. Rowlands (2000) asserts that the world oil consumption is responsible for over 25% of green gas emission (GHG) in the globe.

Due to climate change caused by environmental consequence of carbon emission, the Kyoto Protocol 2015 Paris Conference of the United Nations Framework Convention on Climate Change (UNFCCC) committed the industrialized countries and oil-producing countries to reduce the global temperature by an average of 5.2% (Jeppesen & Folmer, 2001). This is necessary to pursue a sustainable development in a manner that fosters low greenhouse gas emissions and makes finance flows consistent with a pathway towards low emission and climate-resilient development (UNFCCC, 2015).

Nigeria, as a part of the 192 countries that are parties to the Kyoto Protocol, is now committed to climate change policy that promotes low-carbon economy. The country is currently working towards ending gas flaring by 2030, targeting off-grid solar photovoltaic (PV) of 13 gigawatt (13,000Mega Watt), maintaining 2% per year energy efficiency, shifting from car to mass transit transportation, adopting clean technology in oil exploration and ensuring climate smart agriculture and reforestation, among others (Nigerian Federal Ministry of Environment, 2015). Furthermore, the integration of the green financed policy alongside with environmental policy in recent time is another great initiative on the part of the Nigerian government to promote financial investment to renewable energy, energy efficiency, agricultural development and other clean energy ventures. Nigeria is a host to a number of Clean Development Mechanism (CDM) projects and those financed by the Adaptation Fund. All the environmental initiatives and policies are evidence and pointers to the fact that Nigeria, as a treaty to the Kyoto Protocol, is committed to becoming a low-carbon economy in the nearest future. It is therefore pertinent to examine the role of financial intermediation in industrial emissions through loan advancement. Table 1 shows that financial development, industrial production and carbon emission have been growing in Nigeria over time.

However, there is a dearth of empirical studies on the interaction of industrial production, financial development and carbon emissions specifically for oil-producing countries. Zhang (2011) has established for China that financial development acts as an important driver of carbon emission increase. In addition, most empirical studies have focused on the relationship between financial development and economic growth (Anthony et al., 2015; Esso, 2010; Goldsmith, 1969; Jalil & Ma, 2008; Ndebbio, 2004; Ngongang, 2015; Nkoro & Uko, 2013; Samargandi

Table 1 Financial development, industrial production and carbon emission in Nigeria

Year	Financial Dev.	Industrial prod.	Carbon emission
1960	109.33	134	3406.64
1970	351.7	912.5	21,539.96
1980	7457.80	20,174.65	68,154.86
1990	35,436.80	115,591.37	45,375.46
2000	596,001.50	2,359,313.30	79,181.53
2010	10,157,021.20	12,033,196	85,221.10
2014	17,128,980	18,402,191	88,026.30
2018	23,536,260	33,218,329.65	97,000.90

Source: CBN (2019)

et al., 2014; Schumpeter, 1911), while other studies have considered the relationship between financial development and industrial production (Ekor & Adeniyi, 2012; Imoughelle et al., 2013; Neusser & Kugler, 1998; Qing et al., 2014; Udoh & Ogbuagu, 2012). In contrast with this study, Mehrara and Musai (2012); Li et al. (2015); and Hamisu et al. (2015) studied the relationship among financial development, carbon emissions and economic growth. Finally, Gokmenoglu et al. (2015) investigated the relationship among industrialization, financial development and carbon emissions for Turkey. Given the Nigeria's commitment and as a party to the Kyoto Protocol's carbon emission intensity reduction by 2030, this study provides more insight and policy relevance about the dynamic relationship among financial development, industrial production and carbon emission in Nigeria. The remaining paper is as follows. Section 2 deals with the theoretical framework, Sect. 3 is for the empirical analysis, and Sect. 4 gives the discussions of the results. Finally, Sect. 5 concludes.

2 Theoretical Framework

The theoretical framework adopted in this study is in line with Sadorsky (2010) where the financial liberalization theory ties the relationship between financial development and industrial production. The limit to growth theory connects industrial production to carbon emissions. It is based on the notion that rising production and consumption cannot be sustained forever in a finite world without consequences on the environment (Tinbergen & Huetting, 1991). Financial development is linked to industrial production via factor productivity channel where financial innovations and technologies lessen information asymmetries (Baier et al., 2004; King & Levine, 1993; Townsend, 1979). Financial development allows easier access to financial capital, either through lower borrowing costs or through new sources of financing (Gurley & Shaw, 1955; McKinnon, 1973; Shaw, 1973). Also, increased financial development makes it easier for consumers and businesses to save, invest and borrow. As development occurs within an economy's financial services sector, consumers find it easier and cheaper to borrow money and buy goods and services. Producers' motivation to maximize industrial production will lead them to expand existing operations or construct new plants and factories, all of which increase the demand for energy.

Theoretically, the relationships between financial development and carbon emissions have been mixed. Some authors suggest that financial development can help mitigate air pollution (Claessens & Feijen, 2007; Kumbaroglu et al., 2008; Li et al., 2015; Stijn & Feijen, 2007; Tadesse, 2005; Tamazian et al., 2009). These authors viewed that development of financial institutions can reduce the cost of investments and serve as a crucial way of raising funds and an important channel for firms to develop. Therefore, a firm that grows by the help of financial development will likely be more effective in its resource usage and become more efficient in its energy use. And as a result, carbon emissions are expected to diminish. A further argument is

that as firms grow and become institutionalized, their social responsibility towards achieving environment sustainability may be enhanced, which in turn can decrease carbon emissions (Li et al., 2015).

Conversely, Frankel and Romer (1999); Dasgupta et al. (2001); Sadorsky (2010); Zhang (2011); and Gokmenoglu et al. (2015) are the proponents of the view that financial development is an important source of increased carbon emissions. To establish the theoretical link between financial development and carbon emissions, the authors argued that more financial access to firms leads to more expansion and more fossil fuel emission; and this is a significant source behind high level of carbon emissions. More elaborately, the authors argued that financial development aids firms to decrease their financing costs, increase credit channels and spread operational risk, which in turn make firms able to invest more, install new facilities and increase their production capacities, hence increasing the level of carbon emissions produced.

With the development of the financial sector expected to lead the growth of the industrial sector, the increase in industrial production indicates increase energy use and more carbon emissions as the industrial sector is highly dependent on non-clean energy sources (Dasgupta et al., 2001; Frankel & Romer, 1999; Sadorsky, 2010 ; Zhang, 2011). For instance, improved finance to the oil and gas, cement production and manufacturing sector that constitute the Nigeria's industrial sector is expected to increase industrial production and subsequently worsen environmental degradation through increase in carbon emissions. Another line of thought is that financial development especially backed with government regulation and/or institutional policy towards investment into clean energy sources may help decrease carbon emissions (Claessens & Feijen, 2007; Gokmenoglu et al., 2015; Tamazian et al., 2009).

Moreover, the relationship between financial development and carbon emissions can emanate from consumption (Zhang, 2011). The argument is that financial development eases consumers' access to loans, which make them able to acquire costly items such as automobiles, bigger houses, air conditioners and so on, which cause more carbon to be emitted to the environment (Sadorsky, 2010; Zhang, 2011). Thus, empirically, Zhang (2011) has established the causal relationship between carbon emissions and financial development for China. In most recent studies, Jiang and Ma (2019) examined the relationship between financial development and carbon emission on a panel study of 155 countries from 1960 to 2014 using system generalized method of moment. The study found financial development to significantly increase emission on a global scale. Lastly, Bui (2020) investigated the direct and indirect effects of financial development on CO₂ emission using a sample of 100 countries from the year 1990 to 2012. The findings, using both the two and three stage least square, showed positive direct effect of financial development on environmental quality through the energy demand and financial channels.

3 Data Source and Variable Measurement

The major data requirements for this study are financial development measure, industrial production and carbon emissions. The data is annual, and it spans from 1960 to 2018. The data is sourced from various issues of Central Bank of Nigeria (CBN) Statistical Bulletin (2018) and the World Bank Development Indicators (WDI) (2018).

Carbon emissions (CO₂): Carbon is a greenhouse gas emitted from the burning of fossil fuels and natural gases during industrial and consumption activities of solid, liquid gas fuel, gas flaring and those generated during cement production. The CO₂ is measured in kiloton (Kt). This is sourced from WDI (2018).

Financial development (FIN): Financial development is measured by credit to private sector capturing an important activity of the financial sector, which is channeling funds from savers to investors in the private sector (Ang, 2007). This is sourced specifically from the CBN Statistical Bulletin 2018. It is measured in the local unit, naira.

Industrial production (IND): This is the output of the industrial sector measured in the local monetary unit, naira. This includes oil refining and natural gas, cement production, iron ores, solid minerals, mining, quarrying and other manufacturing activities. It is measured as the share of industry in total GDP. This is also sourced from the CBN Statistical Bulletin (2018).

3.1 Descriptive Statistics of Variables

The descriptive statistics gives us insight into essential characteristics (i.e. distribution, symmetry and variability) of the variables used in the analyses. From Table 2, on the average, ₦3,170,413 billion worth of credit went to the private sector. Also, on the average, ₦3,798,443 billion worth of output was from the

Table 2 Descriptive characteristics of the series

Statistic	CRDT	IND	CO ₂
Mean	3,170,413	3,798,443	57,630.48
Median	21892.5	34477.3	59,343.06
Maximum	23,536,260	33,218,330	10,4696.5
Minimum	109.3	134	3406.64
Skewness	2.51	2.09	-0.24
Kurtosis	8.14	6.23	2.04
Jarque-Bera	118.52	64.12	2.65
Probability	[0.0000]	[0.0000]	[0.2656]*

Note 1: *indicates non rejection of normality assumption given that probability value is not lower than 5% significance level

Note 2: CRDT, IND and CO₂ represent credit, industrial production and carbon emissions, respectively

industrial sector; 57,630.5 Kt carbon were emitted into the atmosphere during the period of study. The maximum CO₂ emitted during the study period was 104,696.5 Kt, while the maximum amount of credit that went to the private sector was ₦23,536,260 billion, and the maximum industrial production was ₦33,218,330 billion worth of goods. Examination of the Jarque-Bera test gives information with respect to the distribution of the series. The significance level less than 0.05% indicates the non-rejection of the null hypothesis that the test is normally distributed. Thus, on the basis of this rule, carbon emissions and interest rate can be said to satisfy the normality condition.

3.2 Unit Root Test

The augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1981) and the Phillips-Perron (PP) test (Phillips & Perron, 1988) as shown in Table 3 indicates that all the variables are non-stationary and integrated of order 1. This result is corroborated by the PP test also in Table 3 where all the variables are shown to be integrated of order 1, i.e. stationary after first difference. All the variables are expressed in logarithm.

3.3 Unit Root with Break

Following Perron (1989), unit root process in time series can induce structural break, hence the need to examine the effect of structural breaks in the series. The result as presented in Table 4 shows that structural breaks do not affect the series as they are all still I(1) after accounting for structural breaks.

Table 3 The augmented Dickey-Fuller and Phillips-Perron unit root tests with intercept and linear trend

Test Variable	Augmented Dickey-Fuller			Phillips-Perron		
	Level	First diff	Status	Level	First diff	Status
LCRDT	-2.7710 [0.2141]	-5.11789 [0.0006]*	I (1)	-2.6745 [0.2509]	-5.1634 [0.0005]*	I (1)
LIND	-2.3278 [0.4122]	-6.9838 [0.0000]*	I (1)	-2.4510 [0.3504]	-6.9829 [0.0000]*	I (1)
LCO2	-2.3405 [0.4056]	-6.9650 [0.0000]*	I (1)	-2.2897 [0.4321]	-7.0110 [0.0000]*	I (1)

Note 1: * indicates significance at 1%; ** indicates significance at 5%. The critical values at 1%, 5% and 10% are -4.141, - 3.497 and - 3.254, respectively

Table 4 Augmented Dickey-Fuller structural break test

Variables	Levels	Difference	Break date	Status
LCRDT	-1.8209	-6.0981	2008	I(1)
LIND	-2.596	-7.3728	1974	I(1)
LCO2	-3.3369	-7.8052	1974	I(1)

The critical values at 1%, 5% and 10% are -4.9491, -4.4436 and -4.1938, respectively

4 Model Specification

In line with Fosu and Magnus (2006), Constant and Yaoxing (2010) and Udoh and Ogbuagu (2012), this study proceeds from the simple production function to model the relationship among CO₂, industrial production and financial development in the sampled study. The industrial production function is specified as:

$$IND_t = f(FIN_t) \quad (1)$$

On the basis of the limit to growth model where continued industrial production leads to growth in pollution, we specify a model where environmental pollution measured with carbon emissions is a function of industrial production:

$$CO2_t = f(IND_t) \quad (2)$$

Theoretically, financial development drives carbon emissions through industrial production; hence we can augment Eq. (2) by incorporating Eq. (1) as:

$$CO2_t = f(IND_t, CRDT_t) \quad (3)$$

We can specify Eq. (3) as a linear econometric model as:

$$CO2_t = \alpha + \beta_1 IND_t + \beta_2 CRDT_t + \varepsilon_t \quad (4)$$

4.1 Methodology

To achieve the objective of this study which is to examine the dynamic relationship among financial development, industrial production and carbon emissions, we endogenize our variables and re-specify Eq. (4) as vector autoregressive (VAR) model proposed by Sim (1980). The purpose of VAR is that it helps to solve dynamic relationship among the variable of interest such as the causality analysis. In addition, it also enables researchers to examine the past history of a variable and

other related variables over itself, hence the reason for the adoption of VAR in this study. Thus, a simple VAR model can be written as:

$$\begin{aligned}
 \Delta\text{CO2}_t &= \Omega_1 + \sum_{i=1}^m \Xi_{1i} \Delta\text{CO2}_{t-i} + \sum_{i=1}^n \psi_{1i} \Delta\text{IND}_{t-i} + \sum_{i=1}^p \beta_{1i} \Delta\text{CRDT}_{t-i} + \xi_{1t} \\
 \Delta\text{IND}_t &= \Omega_2 + \sum_{i=1}^m \Xi_{2i} \Delta\text{CO2}_{t-i} + \sum_{i=1}^n \psi_{2i} \Delta\text{IND}_{t-i} + \sum_{i=1}^p \beta_{2i} \Delta\text{CRDT}_{t-i} + \xi_{2t} \\
 \Delta\text{CRDT}_t &= \Omega_3 + \sum_{i=1}^m \Xi_{3i} \Delta\text{CO2}_{t-i} + \sum_{i=1}^n \psi_{3i} \Delta\text{IND}_{t-i} + \sum_{i=1}^p \beta_{3i} \Delta\text{CRDT}_{t-i} + \xi_{3t}
 \end{aligned}
 \tag{5}$$

4.2 Lag Order Selection Criteria

In order to estimate the vector autoregressive model stated in Eq. (8), it is necessary to determine the optimal lag length of the model. To further prevent model misspecification and loss of degrees of freedom, there is the need to determine the optimal lag length before estimation. The selection of lag length rests on the outcomes of the various information criteria of which the Schwarz criterion is adjudged the most reliable. As shown in Table 5, the Schwarz criterion indicates optimal lag order of 1.

4.3 Cointegration Test

This paper employs a multivariate cointegration estimation method developed by Johansen and Juselius (1992). The VAR stated in Eq. (5) can be written in cointegration representation as:

Table 5 VAR lag selection criteria

LAG	LOGL	LR	AIC	SC	HQ
0	-20.976	NA	1.4989	1.9855	1.6794
1	53.046	127.86*	-1.5475*	-0.6960*	-1.2317*
2	58.021	4.5968	-1.2737	-0.0572	-0.8225
3	70.040	16.937	-1.4109	0.1705	-0.8244
4	87.423	22.124	-1.7919	0.1544	-1.0702
5	91.992	5.1916	-1.5905	0.7208	-0.7334

Note: * indicates lag order selected by criterion at 5% significance level. LogL, log likelihood; LR, likelihood ratio; AIC, Akaike information criterion; SC, Schwarz information criterion; HQ, Hannan-Quinn information criterion

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \dots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi Z_{t-1} + \mu + \varepsilon_t \quad t = 1 \dots T \quad (6)$$

where $\Gamma_i = -(1 - \Pi_1 + \dots + \Pi_i)$, $i = 1 \dots k - 1$ and $\Pi = -(1 - \Pi_1 + \dots + \Pi_k)$. Z_t is a q -dimensional vector of stochastic variables, Γ_i are $q \times q$ matrix of the short-run coefficients, and Π is a $q \times q$ matrix of the long-run coefficients. In this paper, $Z_t = \text{CO2}_t, \text{IND}_t, \text{CRDT}_t$ and thus $q = 3$. The variable ordering $Z_t = \text{CO2}_t, \text{IND}_t, \text{CRDT}_t$ is informed by theory and from the work of Gokmenoglu et al. (2015) that carbon emission depends on industrial output and financial development. μ is the constant vector and ε_t is the error term. If $\text{rank}(\rho(\Pi)) = 0$, Eq. (6) is a standard VAR model in first difference form and no cointegration exists in the data. If Π is of full rank, i.e. $\rho(\Pi) = q$, all Z_t series are stationary. If there is a reduced rank such that $\rho(\Pi) = r < q$, Z_t has r cointegration vector and $q - r$ common stochastic trends. In this case, $\Pi = \alpha\beta'$ where α and β are of the dimension $q \times r$. β means the cointegration vectors, while α is the weights attached to them in the VAR model.

Having verified that the variables are of integrated of order one, i.e. $I(1)$ according to the results provided by both the ADF and PP tests in Table 2, then we proceed to investigate the existence of cointegration, i.e. long-run relationship among the variables. The two test statistics assist us in deciding the number of cointegrating relationships among the series. These are the Trace and Maximum Eigen statistics as reported in Tables 4 and 5.

The decision rule for rejecting the null hypothesis for each level of cointegrating relationship from zero (no cointegrating relationship) to the three maximum cointegrating relationships is that we observe the associated probability value of the Trace statistic and Max-Eigen statistic if it is less or greater than the corresponding critical value. From the results of the cointegration in Tables 6 and 7, the null hypothesis that $r = 0$ is rejected by both the Trace and the Max-Eigen statistic, and we accept the alternative hypothesis of $r = 1$, i.e. the first vector in

Table 6 Cointegration rank test (Trace statistic)

Null hypothesis	Alternative hypothesis	Trace statistic	0.05 critical value	Prob.
$r = 0$	$r = 1$	41.07	35.19	[0.0104]**
$r \leq 1$	$r = 2$	14.71	20.26	[0.2431]
$r \leq 2$	$r = 3$	4.66	9.16	[0.3220]

Note: * indicates significance at 1%, ** indicates significance at 5%

Table 7 Cointegration rank test (Maximum Eigenvalue)

Null hypothesis	Alternative hypothesis	Max-Eigen statistic	0.05 critical value	Prob.
$r = 0$	$r = 1$	26.35	22.29	[0.0128]**
$r \leq 1$	$r = 2$	10.04	15.89	[0.3299]
$r \leq 2$	$r = 3$	4.66	9.16	[0.3220]

Note: * indicates significance at 1%, ** indicates significance at 5%

Eq. 5, where CO₂ is the dependent variable, while industrial production and financial development are the explanatory variable. As such, both the Trace statistic and Max-Eigen test indicate one cointegrating relationship among industrial production, financial development and carbon emission. This implies that there exists long-run relationship among the variables in the model. This can be interpreted to mean that the variables are moving together in the long run and one of the variables can be used to affect the others. In other words, the existence of one cointegrating vector indicates at least one direction of causality exists between the variables (Granger, 1969).

4.4 The Error Correction Term and the Causality Test

Following Engle and Granger (1987), we provide a representation of the long- and short-run cointegrating vector $r = 1$ of our variables in an error correction term (ECM) with lag one as:

$$\Delta CO2_t = c_0 + \beta_1 CO2_{t-1} + \beta_2 IND_{t-1} + \beta_3 CRDT_{t-1} + \beta_4 \Delta IND_{t-1} + \beta_5 \Delta CRDT_{t-1} + \beta_6 \Delta CO2_{t-1} + \lambda ECM_{t-1} + \epsilon_t \tag{7}$$

Furthermore, the cointegration results provided in Tables 5 and 6 have provided indications to the existence of causality between the variables of interest. However, it is yet to indicate the direction of causality between the variables. For this purpose, we adopt a bivariate Granger (1969) causality model of our variables which is represented as:

$$\begin{aligned} \Delta CO2_t &= c_1 + \sum_{i=1}^m \beta_i CRDT_{t-i} + \sum_{i=1}^n \alpha_i IND_{t-i} + \epsilon_{1t} \\ \Delta IND_t &= c_2 + \sum_{i=1}^m \theta_i CO2_{t-i} + \sum_{i=1}^n \pi_i CRDT_{t-i} + \epsilon_{2t} \\ \Delta CRDT_t &= c_3 + \sum_{i=1}^m \eta_i CO2_{t-i} + \sum_{i=1}^n \lambda_i IND_{t-i} + \epsilon_{3t} \end{aligned} \tag{8}$$

where c_1, c_2, c_3 are the constant terms, $\Delta CO2_t, \Delta IND_t$ and $\Delta CRDT_t$ in their first difference which are dependent on the past history of one another, while $\epsilon_{1t}, \epsilon_{2t}, \epsilon_{3t}$ are the error terms, respectively. The results of the long-run and the short-run effects with the ECM term and the causality test are presented in Tables 7 and 8.

Table 8 The result of the long, short run and the ECM term. Dependent Variable: CO2

Variables	Coefficient	Std. error	t-Statistic	p-Value
IND(-1)	4.087	1.1913	3.4315	0.00***
CRDT(-1)	-4.0689	1.1955	-3.4007	0.00***
Δ CO2(-1)	0.017	0.1434	0.1186	0.51
Δ IND (-1)	0.2115	0.1282	1.6506	0.13
Δ CRDT(-1)	-0.1245	0.2509	-0.4964	0.34
ECM(-1)	-0.024	0.0176	-1.3642	0.86
Variables	Dependent variable: IND			
CRDT(-1)	-0.9923	2.8934	-5.7823	0.00***
CO2(-1)	0.1897	1.7823	0.1426	0.12
Δ CO2(-1)	-0.1911	0.1829	-1.0452	0.56
Δ IND (-1)	0.1378	0.0716	0.8493	0.42
Δ CRDT(-1)	0.0637	0.3148	0.2024	0.28
ECM(-1)	-0.0122	-0.0122	-0.6859	0.96
Variables	Dependent variable: CRDT			
CO2(-1)	-0.1913	0.4521	-2.1561	0.29
IND(1)	-1.0078	1.8934	-4.1978	0.00***
Δ CO2(-1)	0.0378	0.0716	0.5274	0.73
Δ IND (-1)	-0.0015	0.0635	0.8555	0.91
Δ CRDT(-1)	0.1054	-0.0015	-0.0231	0.22
ECM(-1)	0.0276	0.0071	3.9662	0.00***

*** indicates 1% significance level

5 Results and Discussion

The long-run result is shown in Table 8 for three models (model1, CO2, IND, CRDT; model 2, IND, CO2, CRDT; and model 3, CRDT, IND, CO2).

The result of model 1 indicates that in the long run, industrial production has a significant and positive relationship with carbon emission at 1% significance level over the study period, with a coefficient of 4.0870. This implies that one percent increase in industrial production leads to 4.07% increase in carbon emission in the long run. On the other hand, we found financial development measured as credits to the private sector to have a negative relationship with carbon emission in the long run. One percent increase in financial development leads to 4.07% decrease in carbon emission at 1% significance level. This result is in support of previous studies like Tamazian et al. (2009) and Li et al. (2015) which assert that financial development helps industries through credit accessibility to adopt clean technologies which result to low-carbon emission.

In the short run, we found the immediate past value of carbon emission to insignificantly affect current carbon emission. 1% increase in the previous emission insignificantly increases the current emission by 0.02%. Moreover, we also found industrial production to have insignificant positive effect on carbon emission in the short run. 1% increase in industrial production increases carbon emission by 0.21%

Table. 9 The result of the Granger causality test

Null hypothesis	Obs	F-stat.	Prob.
IND does not Granger cause CO2	59	0.4404	0.509
CO2 does not Granger cause IND		0.0117	0.914
CRDT does not Granger cause CO2	59	0.2525	0.753
CO2 does not Granger cause CRDT		3.7227	0.059**
CRDT does not Granger cause IND	59	0.0726	0.788
IND does not Granger cause CRDT		24.611	0.000*

Note: * and ** denotes the rejection of the null hypothesis at 1% and 10% level of significance

insignificantly in the short run. In contrast, financial development is found to have a negative and insignificant effect on carbon emission. 1% increase in financial development results in 0.12% reduction in carbon emission in the short run. Lastly, the error correction term (ECT) is negative as expected but not statistically significant with a coefficient of -0.02 . The ECM suggests that the deviation of variables from the short- to the long-run equilibrium is small and insignificantly adjusted by 2% per year. The insignificance level of the error correction term confirms the insignificant effects of financial development on carbon emission in the short run.

The causality result in Table 9 shows that the null hypothesis that industrial production does not Granger cause financial development is rejected at 5% significance level. Also, the null hypothesis that carbon emission does not Granger cause financial development is rejected at 10% level of significance. The causality results imply that there are unidirectional causalities. First, the growth of financial development is driven by growth in industrial production. Second, there is a unidirectional causality running from carbon emission to financial development. The unidirectional causality that carbon emission Granger causes financial development in our results confirms the long-run negative effect of financial development on carbon emission and also explains this unidirectional causality. As carbon emission increases due to increase in industrial production and capacities, the increase in demand for more funds would cause development in the financial system to provide funds for adoption of low-carbon technologies which would further mitigate the environmental effects of the initial emission. The outcome of the causality results that both industrial production and carbon emission Granger cause financial development is therefore reasonable and consistent because carbon emission is a by-product of industrial production. For model 2, financial development is found to negatively affect industrial output in the long run at 1% significance level. 1% increase in financial development would reduce industrial output by 0.99%. On the other hand, the short-run and the ECM results are not significant. The results of the third model are different. Although the short-run results are not significant, the ECM term is significant. The long-term result shows negative and significant effect of industrial output on financial development. 1% increase in industrial output would reduce financial development by 1.01%. Lastly, the ECM term is negative and significant at 1% with a value of -0.03 .

We further carried out a robustness check of our result using impulse response function. The result shows carbon emission to respond with positive shock to itself. We further found the response of carbon emission to financial development shocks to be zero throughout the period of study. On the other hand, the response of carbon emission to industrial shock is positive with 0.5% over the horizon. Also, the responses of financial development to carbon emission shocks and industrial output are positive throughout its horizon at 1% and 2%, respectively. Lastly, the response of industrial output to emission, itself and financial development is also positive. The industrial output response to emission shock is 1%, to itself is 3%, while it is 0.5 to financial development. Finally, it is found out that the positive and significant effects of industrial output realized in the ECM model corroborate the result of the impulse response function (Fig. 1).

The diagnostic tests that show the stability and the goodness of fit of our model are presented at the appendix section. The roots within the unit circle suggest the stability of our model, while the non-rejection of the VAR residual serial correlation LM tests at 5% significance level implies absence of residual correlation. All these are indications of unbiasedness and reliability of our results. See the Appendix section for the diagnostic tests.

6 Conclusions and Policy Implication

This study investigated the dynamic relationship among industrial production, financial development and carbon emission in Nigeria. This study is important given the commitment of Nigerian government to the Kyoto Protocol of achieving low-carbon economy by the year 2030 as an oil-producing country. The role financial system plays in contributing to carbon emission of industries would be crucial to the attainment of the Kyoto Protocol. The cointegration result showed that long-run relationship exists among industrial production, financial development and carbon emission. The existence of long-run relationship among the variables is confirmed with the long-run significant impacts of both industrial production and financial development on carbon emission. We conclude that industrial production has a significant positive effect on carbon emission, while financial development has a significant negative effect on carbon emission in Nigeria in the long run. This means that industrial output increases emissions, while financial development reduces it. The same result is also found for the effects of industrial production and financial development on carbon emission in the short run though the effects are not significant. The causality results show both industrial production and carbon emission are the drivers of financial development in Nigeria.

Our findings have policy implications. The significant positive effect of industrial production on emission in the long run indicates that long-term industrial and energy policies that would support the increasing use of less carbon and renewable energy in

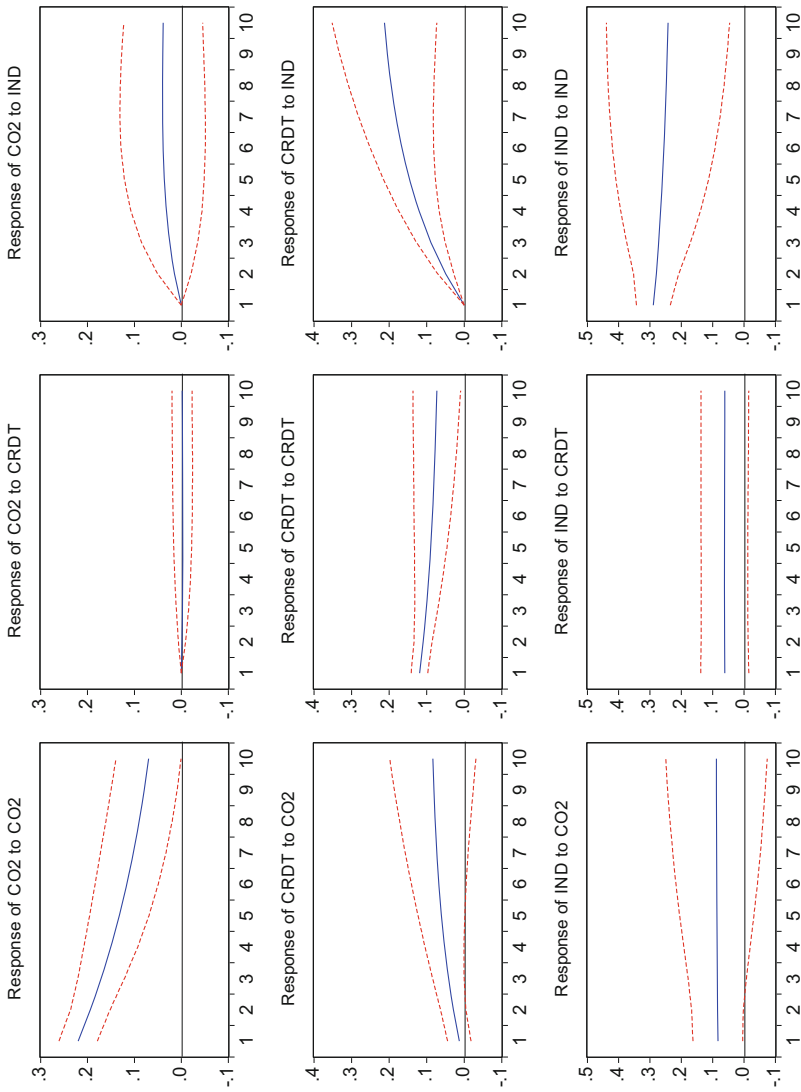
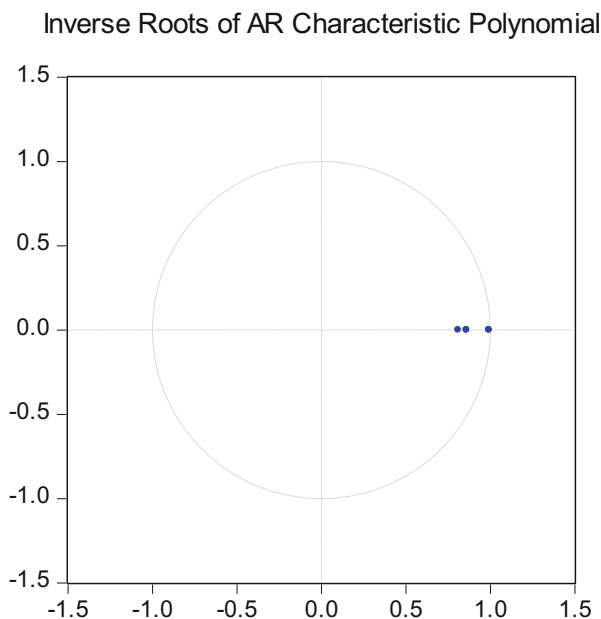


Fig. 1 Impulse response result

production process should be adopted by the industrial and energy sectors in the country. The financial authorities in Nigeria should continue to channel their loans and funds into projects, products and companies that show commitment to low-carbon emission in their production processes given the negative long-run effect of financial development on carbon emission. In conclusion, a more practical way of using financial system and its institution to reduce carbon emission is by interacting Nigerian Federal Ministry of Environment with the Central Bank of Nigeria to offer special loans with lower discount rate to projects that are environmentally friendly. This is with a view to ensuring a more sustainable, low-carbon, climate-resilient economy and as one of the means to achieve the Kyoto Protocol of reduction in global warming in the future.

Appendix

Appendix 1



Appendix 2

VAR Residual Serial Correlation LM Tests		
Null hypothesis: no serial correlation at lag order h at 0.05 significant level		
Date: 10/29/16 Time: 13:45		
Sample: 1960 2018		
Included observations: 54		
Lags	LM-stat	Prob
1	4.479779	0.8771
2	6.578330	0.6809
3	16.11746	0.0645
4	6.905032	0.6470
5	6.027324	0.7372
6	13.19203	0.1541
7	3.338755	0.9493
8	5.724759	0.7671
9	4.022587	0.9099
10	11.46377	0.2453
11	7.578045	0.5772
12	12.68451	0.1774

Probs from chi-square with 9 df

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