FINANCIAL DEVELOPMENT, INDUSTRIAL PRODUCTION AND CARBON EMISSION IN NIGERIA

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Abstract

The study investigates the dynamic interactions among financial development, industrial production and carbon emissions in Nigeria from 1971 to 2020. To achieve this, the functional and structural forms of the production function were estimated for the three models, using the existing theoretical framework. Annual data covering the period from 1971 to 2020 that were sourced from the CBN database, International Monetary Fund (IMF), International Energy Agency (IEA) and World Bank's World Development Indicators were employed for the analysis. Having conducted the unit root and co-integration tests, the ARDL method was employed to derive the long-run regression equation estimates. The findings of the study revealed that both financial development and industrial production have positive effects on carbon emissions in the long run in Nigeria, just as financial development too has effects on carbon emissions and industrial production. Consequently, financial development can be regarded as a major driver of industrial production and carbon emissions in Nigeria. Additionally, industrial production has a positive effect on carbon emissions, indicating that the level of industrialisation is a contributor to the emission of carbon dioxide (CO2). It is therefore recommended that policymakers should pursue financial sector development and industrialisation strategies that encourage long-run environmental sustainability.

Keywords: Financial development, Industrial production, Carbon emissions, and Nigeria.

1. Introduction

In recent decades, Nigeria has experienced a significant economic transformation marked by rapid financial development and industrialisation. While these changes contribute to economic growth and technological advancement, they also raise concerns about their environmental repercussions, particularly in terms of carbon emissions (Li et al., 2015). The interplay between financial development, industrialisation, and carbon emissions presents a complex challenge that demands attention and investigation. Nigeria, as an emerging economy, has witnessed substantial strides in financial sector expansion and embarked on policies aimed at industrial development. The burgeoning financial sector, characterised by increased banking activities, capital mobilisation, and investment, has played a pivotal role in fostering industrialisation. These industrial-related policies targeted at improving industrial activities have been identified as being instrumental in propelling the country towards becoming a regional economic powerhouse. However, the environmental fallout of rapid industrialisation, notably the surge in carbon emissions, poses a critical dilemma (Stern, 2004; Edenhofer et al., 2012).

The nexus between financial development and industrialisation brings to light a nuanced relationship. On the one hand, a well-developed financial sector can facilitate access to capital, encourage innovation, and bolster industrial productivity (Schumpeter, 1911; Goldsmith, 1969; Mckinnon, 1973; Shaw, 1973). Yet, on the other hand, the indiscriminate pursuit of industrialisation may lead to environmental degradation, particularly through increased carbon emissions (Sambo et al., 2021; Onifade et al., 2020). Consequently, this raises pertinent questions about the sustainability of the current development trajectory in Nigeria. The literature on the subject provides valuable insights into the global context of financial development, industrialisation, and carbon emissions. Studies such as Lucas (1988), Stern (1989) and Qing et al., (2014) underscore the intricate links between financial development and industrial growth, emphasising the positive externalities that can result from a well-functioning financial sector. Simultaneously, a growing body of research highlights the adverse environmental consequences of unrestricted industrialisation, with carbon emissions emerging as a focal point of concern due to their role in climate change (Akpan & Akpan, 2012).

However, the specific dynamics of the relationship between financial development, industrialization and carbon emissions within the Nigerian context remain underexplored. Nigeria's unique economic landscape, characterised by a rich endowment of natural resources, an increasing population, diverse industrial sectors and carbon emissions necessitates a focused examination. To create policies that effectively balance economic growth with environmental sustainability, it is essential to comprehend how industrialisation and financial development contribute to carbon emissions in Nigeria.

The rest of the paper is organised as follows: the review of the relevant literature is done in the second section while the third section deals with the methodology. The presentation and discussion of the results obtained from data analysis are considered in the fourth section while the conclusion and recommendations of the paper are discussed in the fifth section.

2.0 Literature Review

2.1 Theoretical Review

The three main theories that are reviewed in this study are the Industrial Theory of Nicholas Kaldor, the Financial Liberalisation Theory and the Limit to Growth Theory. This study reviews the Industrial Theory of Nicholas Kaldor because it explains the role of the industrial sector on economic and factor productivity growth. Also, Financial Liberalisation Theory explains the role of financial development on the real sector economy while the Limit to Growth Theory explains the effect of industrial production on carbon emissions.

According to the narrative of Pons-Novell and Viladecans-Marsal, 1998 as cited in Teshome (2014), Kaldor's Industrial Theory is based on three laws that emphasize the importance of the industrial sector to an economy. The first law sees an increase in industrial output as the basis for increases in the national output. The second law states that the key to sustaining competitiveness and productivity growth is the commitment to technology and innovation. The third law sees the industrial sector leading in innovation and productivity that benefits spread to other sectors of the economy. In the same way, the increased innovation and creativity in the industrial sector will increase economic growth. The theory argues that economic growth is based on the increasing returns or economics of scale in the economy and that the sector with a higher return of economics of scale determines the economic growth of a given country. Further, labour productivity would increase in the industrial sector due to specialisation and increasing returns in the sector. This indicates how the industrial sector is playing a major role in economic growth and increasing factor or labour productivity. In other words, the industrial sector is the engine of economic growth.

Concerning the Financial Liberalisation Theory of McKinnon (1973) and Shaw (1973), the theory posits that well-functioning financial institutions can promote overall economic efficiency, create and expand liquidity, mobilise savings, enhance capital accumulation, transfer resources from traditional sectors to growth-inducing sectors and also promote a competent entrepreneurial response in the real sectors of the economy (McKinnon, 1973; Shaw, 1973). The main message of the theory is that financial institutions are crucial for increasing the productive capacity of the economy and thus countries with better-developed financial systems are expected to grow faster (Orisanwo (2013), Campos et al., 2012; Zhang et al., 2012). McKinnon (1973) and Shaw (1973) argued that the repressed financial markets discourage savings, retards the efficient allocation of resources, increase the segmentation of financial markets and constrain investment. The theory, therefore, posits that the liberalisation from repressive conditions would induce savings, investment and growth. The authors concluded that financial deepening increases the rate of domestic savings, and this lowers the cost of borrowing and thus stimulates investment.

Unlike Kaldor's theory, the Limit to Growth Theory of Meadows et al., (1972) asserts that pollution is the result of economic activities of production and consumption which have an adverse effect on productivity because production activities of the industrial sector promote the consumption of fossil fuels and natural gases (Torras & Boyce, 2008). The Theory assumes that population and industrial capital would grow exponentially, leading to a similar growth in demand for food and non-renewable energies and in pollution. The theory posits that the continued growth of population, food production and industrial production will stretch the world economy to its limits in terms of non-renewable resources, agricultural land and the earth's capacity to absorb excessive pollution (Stephen, 2014). It is based on the notion that rising production, population growth and consumption cannot be sustained forever in a finite world without consequences on the environment (Tinbergen & Hueting, 1991). In conclusion, pollution impacts negatively due to an adverse effect of carbon emissions on the health of workers and the productivity of both labour

and land. The theoretical frameworks that formed the basis of the model that is estimated in this study are the financial liberalisation theory and the limit to growth theory this is because financial liberalisation theory explains the role of financial development on the real sector economy while the limit to growth theory explains the effect of industrial production on carbon emissions.

2.2 Empirical Review

Several studies have been conducted on financial development, industrial production and carbon emissions globally. However, only a few studies have focused on Nigeria. But, for this review and the sake of brevity, only those with recent methodologies as well as the most recent data sets are considered for review.

Beginning with the literature exploring the relationship between financial development and carbon emissions, Mensah and Abdul-Mumuni (2022) conducted a study to analyse the long-term relationship between financial development and carbon emissions. They employed the autoregressive distributed lag approach (ARDL) and found evidence of a positive long-term effect of financial development on carbon emissions. Other studies that showed the positive effect of financial development on carbon emissions include the works of Boutabba (2014), Al-mutali et al., (2015), Liu and Liu (2021), and Huang and Guo (2022). In contrast, Yang et al. (2022) conducted a study examining the long-term association between financial development and carbon emissions, using the ARDL approach. The findings of the study revealed that financial development has a negative effect on carbon emissions. Other studies conducted by Shahbaz et al. (2013), Salahuddin et al. (2018), Zhao et al. (2022), and Olayungbo et al. (2022) similarly reported that financial development has a negative effect on carbon emissions.

Concerning the relationship between financial development and industrialisation, Zhang et al. (2019) conducted a study to explore the effect of financial development on improving the quality of manufacturing capabilities. Their findings revealed that financial development contributes significantly to the improvement of industrial output. Similarly, other studies conducted by Macchiavello (2011), Liu and Liao (2017), Yang and Sun (2020), Wang (2022), and Ai et al. (2023) have also reported positive effects of financial development on industrialisation. In contrast, Beck and Levine (2002), Rajan (2006), and Bui (2020) conducted studies examining the relationship between financial development and industrialisation, and their findings indicated a negative effect of financial development on industrialisation.

Concerning the studies on the relationship between industrialisation and carbon emissions, Liu et al. (2022) conducted a study on the relationship between industrialisation and carbon emissions. They specifically investigated the effects of industrial structure on carbon emissions and found that industrialisation has a positive effect on carbon emissions. Other studies indicating the positive effect of industrialisation on carbon emissions can be found in the studies conducted by Lah (2015), Ma et al. (2019), Zhao et al. (2022), and Zhicheng et al. (2023). In contrast, Skjaerseth and Skodvin (2018), Wu et al. (2019), and Juliansyah (2019) conducted studies examining the relationship between industrialisation and carbon emissions and their findings indicate that industrialisation has a negative effect on carbon emissions.

In conclusion, the following gaps in the literature are noteworthy. Attention has been paid to the relationship between financial development and industrial production with less attention given to the relationship between industrial production and carbon emissions, especially in Nigeria, despite the evidence of large industrial production causing carbon emissions. There are also few empirical studies on the dynamic relationship between financial development, industrial production and carbon emissions generally and specifically for Nigeria.

3.0 Methodology

3.1 Theoretical Framework Underpinning the Specified Model

The theoretical frameworks that formed the basis of the model that is estimated in this study are the financial liberalisation theory and the limit to growth theory which are in line with Sadorsky (2010). The choice of financial liberalisation theory is found to be relevant because it posits a positive effect of financial development on the real sector economy, including industrial production. The Limit to Growth theory, on the other hand, is relevant because it independently and explicitly postulates a positive effect of industrial production on carbon emissions.

Financial development is linked to industrial production via factor productivity channels, whereby financial innovations and technologies lessen information asymmetries (Townsend, 1979; King & Levine, 1993; Baier et al., 2004). The development of the financial sector is expected to lead to the growth of the industrial sector and the increase in industrial production, in turn, leads to increased energy use and more carbon emissions as the industrial sector is highly dependent on non-clean energy sources (Frankel & Romer, 1999; Dasgupta et al., 2001; Sadorsky, 2010; Zhang, 2011). Thus, while financial development may directly lead to increased industrial production, the ultimate effect of financial development on carbon emissions can be established via the link provided by industrial production, meaning that industrial production is an interface or go-between regarding the effect of financial development on carbon emissions. But, also, the effect of financial development on carbon emissions can emanate from consumption. The argument is that financial development eases consumers' access to loans, which makes them able to acquire costly items such as automobiles, bigger houses, air conditioners, and so on, which cause more carbon to be emitted (Sadorsky, 2010 cited in Korhan et al., 2015). However, there is no theoretical basis to expect carbon emissions to drive financial development.

3.2 Model Specification

This study starts from the fact that industrialisation (IND) is often specified as a function of labour (L) and capital (K), which is in line with studies such as Fosu and Magmus (2006); Constant and Yaoxing (2010); Udoh and Ugbuagu (2012). In addition to labour and capital as primary factor inputs, studies have posited industrialisation to be determined by the level of financial development. Following the studies of Mckinon (1973) and Shaw (1973), financial development, in turn, is posited to be a function of credit availability and interest rate. Therefore, the industrialisation relationship can be specified as:

$$IND_t = f(FIND_t, INT_t, K_t, L_t) \quad (1)$$

Based on the Limit to Growth model, according to which continued industrial production leads to growth in pollution, one can 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 and consumption activities. Hence, one can incorporate (1) into (2) and add energy consumption, GDP per capita and urbanisation. Following previous studies such as Bayer et al., 2021; Zhou et al., 2022; and Chen et al., 2022, among others, energy consumption, GDP per capita and urbanisation are included in the model based on the role they play as the major determinants of carbon emissions (CO2). Thus, the model becomes:

$$CO2_t = f(FIND_t, INT_t, K_t, L_t, ECONS_t, PCGDP_t, URB_t) \quad (3)$$

where CO2 = carbon emission; FIND = fianacial development indicator; INT = interest rate; K = capital stock; L = Labour; ECONS = energy consumption; PCGDP = Per capita real GDP and URB = urbanisation.

The specific econometric model to be estimated is derived from the functional form of the CO2 emissions production function in Equation (3). Starting with this functional form and, after separating it and adding the intercept and the error terms β_0 and u respectively, the equation is transformed into Equation (4) thus:

$$CO2_t = \beta_0 + \beta_1 FIND_t + \beta_2 INT_t + \beta_3 K_t + \beta_4 L_t + \beta_5 ECONS_t + \beta_6 PCGDP + \beta_7 URB + u_t \ldots\ldots \ldots(4)$$

where $\beta_1, \beta_3, \ \beta_4, \beta_5, \beta_6 \ and \ \beta_7 > 0$; and $\beta_2 < 0$.

In addition, to examine the relationship between financial development and industrialisation, a structural form of equation is specified. The purpose of formulating a structural equation is to understand the intricate interplay between these variables (i.e. financial development and industrialisation). By considering factors such as credit to the private sector, interest rates, capital stock, and quantity of labour, this analysis seeks to discern how financial development influences industrialisation processes. Credit availability affects investment decisions and facilitates the expansion of industries, while interest rates influence borrowing costs and investment incentives. Also, the levels of capital stock and labour quantity reflect the productive capacity of industries, with financial development potentially influencing their accumulation and utilisation. By highlighting and capturing these relationships through a structural equation, this study provides insight into the mechanisms driving industrialisation. The structural form of the equation is thus defined as:

$$IND_t = \beta_0 + \beta_1 FIND_t + \beta_2 INT_t + \beta_3 K_t + \beta_4 L_t + u_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ \ldots \ldots \ldots \ldots \ldots \ldots .. (5)$$

where $\beta_1, \beta_3 \ and \ \beta_4 > 0$; and $\beta_2 < 0$.

Also, to investigate the relationship between industrialisation and carbon emissions, a structural equation is defined. The purpose of formulating a structural equation to examine the relationship between industrialisation and carbon emissions is to understand the complex dynamics between these variables and their implications for environmental sustainability. By considering factors such as industrial production, energy consumption, real per capita GDP, and urbanisation, this analysis aims to elucidate how industrialisation patterns influence carbon emissions. Industrial production directly contributes to emissions through manufacturing processes, while energy consumption, often associated with industrial activities, is also a major source of carbon emissions. Real per capita GDP reflects the tempo of economic activities, which can drive industrialisation and subsequently affect emissions levels. Additionally, urbanisation, linked to industrial development, affects energy demand and transportation patterns, further influencing carbon emissions. Through a structural equation approach, this study intends to examine the relationship between these variables and devise strategies to mitigate carbon emissions while promoting industrial development and sustainable economic growth. The structural form equation is defined as follows:

$$CO2_t = \beta_0 + \beta_1 IND_t + \beta_2 ECONS_t + \beta_3 PCGDP + \beta_4 URB + u_t \ \ldots \ldots \ldots \ldots \ldots \ldots \ \ldots \ldots \ldots \ldots \ldots .. \ (6)$$

where $\beta_1, \beta_2, \beta_3 \ and \ \beta_4 > 0$.

3.3 Measurement of variables

Concerning the definitions of the variables and how they are measured, carbon dioxide or CO2 is a greenhouse gas emitted from the burning of fuels and natural gases during industrial and consumption activities and those generated during cement production. It is measured in Kilotons (kt). Also, financial development or FIND is measured by credit to the private sector capturing an important activity of the financial sector, which is channelling funds from savers to investors in the private sector (Ang, 2007). In line with the financial liberalisation theory, it is measured with credit to the private sector and it is expressed in million Naira (at 1985 constant value). Similarly, industrial production or IND is the output of the manufacturing sector, which includes oil refining and natural gas, cement production, iron ores, solid minerals, mining, quarrying and other manufacturing activities and it is measured in million Naira (at 2010 constant value). In the same vein, real interest rate or INT is the lending rate less rate of inflation, measured as an annual percentage change in CPI.

Capital stock or K is the private capital stock accumulated in the economy. It is measured in million Naira (at 2017 constant value). Labour or L is described as the amount of physical, mental and social effort used to produce goods and services and it is measured in millions of workers. Also, energy consumption or ECONS is measured as fossil fuel energy consumption, which comprises coal, oil, petroleum and natural gas products. Measured as the ratio of fossil fuel energy to total energy consumption, it is sourced from the International Energy Agency, IEA (2022). Also, urbanisation or URB refers to people living in urban areas, which the National Bureau of Statistics defines as a percentage of the total population living in cities or towns. The data is sourced from the World Bank's World Development Indicators. Per capita GDP or PCGDP is measured as the value of total goods and services (at 2010 constant value) produced in a country in a particular year divided by the total population of the country and it is sourced from the CBN Statistical Bulletin (2022).

4.0 Results and Discussion

4.1 Pre-estimation Analysis

4.1.1 Descriptive Statistics

Table 1 presents the summary statistics. The table consists of the columns for the variables and their description, mean, standard deviation (std. Dev.), minimum (min) and maximum (max) values.

Table 1: The Descriptive Statistics

Variables	Description	Mean	Std. Dev.	Min.	Max.
CO2	Carbon emissions – Kilotons (kt)	6,700	15.75	4,406	97,450
FIND	Credit to the private sector - billion naira (in 1985 constant value)	11	5.35	6	23
IND	Industrial Output – million naira (in 2010 constant value)	230	13.05	134	347
ECONS	Energy consumption – % of Fossil fuel energy to total energy consumption	10	3.24	6	23
INT.	Interest rate - lending rate less rate of inflation in %	-0.067	0.138	-0.585	0.158
K	Capital stock – billion naira (in 2017 constant value of Naira)	590	1.70	576	645
L	Labour force – millions of workers	4	1.60	3	8
URB	Urbanisation – urban as % of the total population	29	10.45	22	49
PCGDP	Per capita real GDP (in 2010 constant value of Naira)	259	59.92	199	386

Source: Author's Computation, 2023.

Explanatory notes: Obs = Observation, Std. Dev. = Standard Deviation, Min. = Minimum and Max. = Maximum. The number of observations in all cases is 50, from 1971 to 2020.

Table 1 summarises the descriptive statistics for all variables in the study. The table provides information on the mean, minimum, and maximum values of each variable, allowing for a comprehensive understanding of the data. The table reveals that the mean for carbon emission

(CO2), financial development indicator (FIND), industrial output (IND), energy consumption (ECONS), interest rate (INT), capital stock (K), Labour (L), urbanization (URB) and Per capita real GDP (PCGDP) throughout 1971 to 2020 period is 6,700 Kt, ₦ 11 billion, ₦ 230 million, 10%, -0.067%, ₦ 590 billion, 4 million, 29% and ₦ 259 respectively while their corresponding standard deviations are 15.75, 5.35, 13.05, 3.24, 0.138, 1.70, 1.60, 10.45 and 59.92 respectively.

4.1.2. Results of Correlation Analysis

The correlation matrix of Table 2 displays the Spearman or simple correlation coefficients, which characterise the nature of the relationships between all the variables in the model.
In this investigation, a 5% p-value was selected as the cut-off significance level.

Correlation is assumed to exist only when its p-value is less than or equal to 5%.

Table 2: The Correlation Matrix

	1	2	3	4	5	6	7	8	9
VARIABLE	CO2	FIND	IND	INT	K	L	ECON	PCGDP	URB
1. CO2	1.000 -----								
2. FIND	0.484 (0.007)	1.000 -----							
3. IND	0.413 (0.023)	0.834 (0.000)	1.000 -----						
4. INT	-0.169 (0.371)	-0.180 (0.339)	-0.136 (0.471)	1.000 -----					
5. K	0.402 (0.027)	0.531 (0.000)	0.791 (0.000)	-0.214 (0.254)	1.000 -----				
6. L	0.518 (0.001)	0.672 (0.000)	0.537 (0.000)	-0.205 (0.276)	0.509 (0.254)	1.000 -----			
7. ECONS	0.555 (0.000)	0.653 (0.000)	0.520 (0.003)	-0.155 (0.412)	0.712 (0.000)	0.750 (0.000)	1.000 -----		
8. PCGDP	0.438 (0.015)	0.693 (0.000)	0.557 (0.003)	0.074 (0.696)	0.769 (0.000)	0.631 (0.000)	0.602 (0.000)	1.000 -----	
9. URB	0.343 (0.028)	0.600 (0.000)	0.398 (0.010)	0.163 (0.313)	0.566 (0.000)	0.408 (0.008)	0.378 (0.015)	0.456 (0.003)	1.000 -----

Source: Author's Computation, 2023.
Explanatory notes: CO2 = carbon emission, FIND = financial development indicator, IND = industrial output, INT = interest rate, K = capital stock, L = Labour, ECONS = energy consumption, PCGDP = Per capita real GDP and URB = urbanisation. Also, it is the p-values that are reported in parentheses beneath the correlation coefficients.

Table 2, indicates that in the first column, CO2 is positively correlated with FIND, IND, ECONS, PCGDP and URB; negatively correlated with K and L and uncorrelated with INT. Table 2's second column and second row demonstrate that FIND is uncorrelated with INT and positively linked with CO2, IND, K, L, ECONS, PCGDP, and URB. Table 2's third column and row demonstrate that IND is uncorrelated with INT and positively linked with CO2, FIND, K, L, ECONS, PCGDP, and URB. Additionally, Table 2's fourth row and column demonstrate that does not correlate with other study variables. Table 2's fifth row and column show that K is uncorrelated with INT and positively linked with CO2, FIND, IND, K, L, ECONS, PCGDP and URB. Table 2's sixth row and sixth column demonstrated that L has an uncorrelated relationship with INT and a positive correlation with CO2, FIND, IND, K, L, ECONS, PCGDP, and URB. Table 2's seventh row and column demonstrate that ECON is uncorrelated with INT and positively linked with CO2, FIND,

IND, K, L, PCGDP and URB. Table 2's eighth row and eighth column demonstrated that PCGDP is uncorrelated with INT and positively correlated with CO2, FIND, IND, K, L, ECONS, and URB. Lastly, Table 2's ninth row demonstrates that URB is uncorrelated with INT and positively linked with CO2, FIND, IND, K, L, ECONS, and URB. But none of the study's explanatory variable pairs have a high degree of correlation of up to or close to 0.80 in absolute terms, which is generally regarded as a benchmark based on thumb by Asteriou and Hall (2014), above which multicollinearity becomes a cause of concern.

4.1.3 Results of the Unit Root Tests

Table 3 presents the results of the unit root test for the variables used in the study. To confirm the sequence of variable integration, the Augmented Dickey-Fuller test is utilized. If the p-value of the t-statistic is less than the study's specified cut-off of a 5 per cent significance level, the null hypothesis that a variable has a unit root (i.e., is a non-stationary series) is rejected; otherwise, the null hypothesis is accepted.

Table 3: Unit Root Test Results

Variable	T-statistics	P-value	Order of Integration	Conclusion regarding the order of integration
lnCO2	-2.402	0.407	Level	I(1)
	-5.310	0.000	1st Difference	
lnFIND	-1.945	0.607	Level	I(1)
	-5.343	0.000	1st Difference	
lnIND	-4.820	0.315	Level	I(1)
	-7.076	0.000	1st Difference	
INT	-5.619	0.000	Level	I(0)
lnK	-0.129	0.619	Level	
	-5.107	0.000	1st Difference	I(1)
lnL	-1.839	0.711	Level	I(1)
	-6.772	0.000	1st Difference	
lnECONS	-2.175	0.456	Level	
	-5.412	0.000	1st Difference	I(1)
lnPCGDP	-2.010	0.280	Level	
	-4.701	0.000	1st Difference	I(1)
lnURB	-2.157	0.222	Level	
	-6.794	0.000	1st Difference	I(1)

Source: Author's Computation, 2023.

Explanatory notes: *CO2 = carbon emission, FIND = financial development indicator, IND = industrial output, INT = interest rate, K = capital stock, L = Labour, ECONS = energy consumption, PCGDP = Per capita real GDP and URB = urbanisation and "ln" before an acronym indicates that is in natural logarithm. A coefficient is adjudged to be significant if the p-value of its t-statistic is less than 5% significant level adopted in the study, which indicates that the null hypothesis is rejected and hence, the variable is stationary, but otherwise (i.e., the p-value is greater than 5%), the null hypothesis is rejected, meaning that the variable contains unit root.*

The results of the Augmented Dickey-Fuller unit root test in Table 3 reveal that only one (which is INT) out of the six variables is stationary at level or I(0) because the p-value of its unit root test statistics is less than 5% while the remaining five are stationary only after being first-differenced so they are I(1) in their level form. This implies that each model has a mix of I(0) and I(1) series (except the CO2 model that excludes the financial development factors) and the dependent variables, i.e., CO2 and IND, are both I(1). Based on this, the Autoregressive Distributed Lagged (ARDL) Bound test method is suitable for ascertaining the co-integration status of each of the models.

4.1.4. Co-integration Test

The results of Paseran, Shin and Smith ARDL Bounds tests that were conducted to ascertain the co-integration status of each of the models are presented in Table

Table 4: Results of Bound Tests for Co-integration

Dependent Variable	F-Statistic	Lower Bound	Upper Bound	K	Co-integration Status	Action to be Taken
lnCO2 for financial development variables	6.60	2.86	4.01	7	Co-integrated	Estimate with the ARDL method and report only the long-run estimates.
lnIND	3.45	2.14	3.33	4	Co-integrated	Estimate with the ARDL method and report only the long-run estimates.
lnCO2 for industrialisation variables	3.70	2.06	3.24	4	Co-integrated	Estimate with the ARDL method and report only the long-run estimates.

Source: Author's Computation, 2023.

Explanatory notes: *The decision rule is to reject the null hypothesis of no integration if the F-statistics is greater than the upper bound (I_1) and accept the null hypothesis of no co-integration if the F-statistics is less than the lower bound (Io). But if the F-statistic is between the lower bound (Io) and upper bound (I_1), the result of the test is said to be inconclusive and the null hypothesis of no co-integration is accepted.*

According to Table 4 above, all three equations have F-statistics of 3.77, 3.45, and 3.70, which are greater than the respective upper bound of 3.35, 3.33 and 3.24, as well as the lower bound of 2.06, 2.14 and 2.06. This suggests that there is a long-run relationship between the model and the cointegration, indicating the applicability of the long-run ARDL estimate.

4.1.5 Results of Regression Analysis

The ARDL long-run estimates are presented for the three models (i.e., Equations 4, 5 and 6). Concerning all the model estimates, the coefficients, t-statistics and p-values are reported in the first, second, and third columns respectively. In this study, a coefficient or parameter is deemed to be statistically significant and, hence, the associated explanatory variable is adjudged to affect the dependent variable only if the p-value is not more than the 5% level of significance.

Table 5: Long-run ARDL Estimates of the Regression Equations for the CO2 and IND

	lnCO2			lnIND			lnCO2		
Variable	Coeff	t-stat	p-value	Coeff	t-stat	p-value	Coeff	t-stat	p-value
lnFIND	0.649	4.600	0.000	0.409	4.750	0.000	--	--	--
lnIND	--	--	--	--	--	--	0.219	2.220	0.033
INT	-0.297	-1.703	0.315	-0.217	-1.200	0.235	--	--	--
lnK	0.577	3.503	0.001	0.519	2.711	0.011	--	--	--
lnL	0.192	2.980	0.004	0.215	2.500	0.018	--	--	--
lnECONS	0.141	2.250	0.030	--	--	--	0.309	4.550	0.000
lnPCGDP	0.139	2.313	0.019	--	--	--	0.168	2.210	0.041
lnURB	0.117	4.800	0.000	--	--	--	0.141	2.670	0.013
C	7.401	2.930	0.004	5.100	1.780	0.083	4.093	1.210	0.234
Observations	50			50			50		

R^2	0.73			0.79			0.75		
Adj-R^2	0.71			0.84			0.79		
F-statistic	15.850	--	0.000	19.350	--	0.000	12.290	--	0.000
Breush-Pagan Test Statistic for Heteroscedasticity	2.213	--	0.370	1.783	--	0.570	1.490	--	0.510
Breush-Godfrey Test Statistic for Serial Correlation	1.630	--	0.427	2.450	--	0.278	1.730	--	0.500
VIF Test Statistic for Multicollinearity	2.33			2.75			2.44		
Jacque-Bera Test Statistic for Normality test	1.349	--	0.493	2.200	--	0.170	2.700	--	0.253

Source: Author's Computation, 2023.

Explanatory notes: *The following are the meanings of acronyms: FIND = financial development indicator,*
IND = industrial output, INT = interest rate, K = capital stock, L = labour, ECON = energy consumption, PCGDP = Per capita real GDP and URB = urbanisation and the "ln" before an acronym indicates that is in natural logarithm. A coefficient is adjudged to be significant if the p-value of its t-statistic is less than or equal to 5% critical value, with the decision rule being to reject the null hypothesis that the coefficient is not statistically significant if its t-statistic's p-value is less than or equal to 5% and to accept it if otherwise.

The results in Table 5 showed that the values of the R^2 were 73%, 79% and 75% respectively. This implies that the variations in the explanatory variables included in the models explained 73%, 79% and 75% of the variation in the three models. Also, the result in the same table shows that the F-statistic for all the R^2 values is statistically significant at 5%, as their p-values are all much lower than 0.05. This connotes that there is high explanatory power and the fitness of each of the models.

Also, the results of the Variance Inflation Factor (VIF) test conducted to detect the multicollinearity problem indicate that, concerning each model, the value of the VIF statistic obtained, which ranges between 2.23 and 2.75, is not greater than the common cutoff value of 5, at which multicollinearity may become problematic (Asteriou & Stephen, 2016). Similarly, the result of the Breusch-Pagan test indicates that the model estimates are not suffering from the problem of heteroscedasticity as the p-values of its test statistics are between 0.370 and 0.570, which are all higher than the 5% threshold, in the same manner that the result of Breusch-Godfrey LM test too reveals an absence of autocorrelation in the models, as the p-values of its test statistics are between 0.278 and 0.500, all of which do not fall below the 5% cut-off. Ultimately, the Jacque-Berra test result, which was performed to ascertain whether the residual distribution was normally distributed or not, shows that since the test statistics' p-values fall between 0.170 and 0.493, it is greater than the 5% threshold.

4.1.6 Discussion of Results and Implication of Findings

After assessing the results of the diagnostic tests, the following section discusses how well each particular variable in the models performed.

The findings presented in the table show that Models 1 and 2 have coefficients of the financial development indicator (FIND) of 0.649 and 0.409, respectively, with p-values of 0.000 and 0.000. The fact the coefficients are statistically significant at the 5% level indicates that FIND has the predicted positive sign in the models for industrialization and carbon emissions, respectively. This is thus robust evidence that financial development has the expected positive effects on carbon emission and industrialisation, with this evidence also agreeing with findings from most previous studies, such as Odhiambo (2020) and Raghutla & Chittedi (2020). As previously stated, FIND's beneficial effects on industrialisation and carbon emissions can be linked to the private sector's greater access to financing. According to the previously mentioned rationale, financial development initiatives can accelerate industrialisation and raise carbon emissions as a result of heightened industrial activity brought on by increased investment.

The coefficient of industrial output (IND) in the estimated equation (3) is 0.219, with a p-value of 0.033 respectively. Thus, the findings show that IND has the expected positive effect on carbon emission, which is in line with the a priori expectation and findings from most previous studies, like Zhou et al. (2022) and Wang (2023). The positive effect of IND on carbon emission is, as discussed previously, attributed to the link between higher levels of industrial production and increased carbon emissions. This is primarily caused by the direct release of greenhouse gases and pollutants from industrial-related operations.

The results indicate that the coefficients of interest rate (INT) in the two equations about the industrialization and carbon emission models are -0.217 and -0.297, respectively, with pvalues of 0.235 and 0.315. Thus, it follows that INT has no bearing on industrialisation or carbon emissions. This should be the case because INT doesn't affect IND or CO2, which is ironic given INT is meant to affect CO2 through IND. The lack of its effect on IND, in turn, could be attributed to the presence of alternative financing channels for industrial activities, like the dominant informal lending channels, equity financing, retained earnings or government subsidies.

Also, the coefficients of capital stock (K) in the estimated equations are 0.577 and 0.519, with 0.001 and 0.011 as the respective p-values. It can therefore be concluded that capital stock has the expected positive effect on carbon emission and industrialisation, which is in line with the a priori expectation stated in the study and findings from most previous studies such as Singh and Kumar (2021) and Meng et al. (2022). The positive effect of capital stock, as a factor input in industrial production and, through this, as a determinant of carbon emissions, may thus be attributed to its ability to promote industrial expansion. This, in turn, can lead to higher levels of carbon emissions due to increased investments in industries that are known to contribute to pollution. The coefficients of the labour force (L) in the estimated equations are 0.192 and 0.218, with 0.004 and 0.018 as the corresponding p-values. According to this, both Model 1 and 2’s coefficients of L are positive and statistically significant, indicating that the number of workers has the anticipated positive impact on industrialisation and carbon emissions. This is consistent with the study’s earlier a priori expectation and backed by the results of the majority of prior research, including

Aprilia (2017) and Ditta et al. (2023). Similar to the channels just examined for capital stock (K), the observed positive impact of labour on industrialisation and carbon emissions follows the same path.

In the same manner, the coefficients of energy consumption (ECONS) in Models 1 and 3 are 0.141 and 0.309, with p-values of 0.030 and 0.000 respectively. There is, therefore, evidence that energy consumption has the expected positive effect on carbon emission, in line with the a priori expectation earlier stated in the study and the findings of a number of the previous studies, e.g. Boutabba (2014) and Zhou et al. (2022). In consonance with the explanation put forward earlier in the paper, the reason for this observed positive effect of ECONS on carbon emissions is that, as industrial activity increases, so does energy consumption, resulting in an increase in carbon emissions due to the increased demand for energy-intensive processes within industrial activities. The result in the table also indicates that the coefficients of per capita real GDP (PCGDP) in Models 1 and 3 are 0.139 and 0.168, with p-values of 0.019 and 0.041 respectively. Thus, PCGDP has the expected positive effect on carbon emission, a finding that is in line with the a priori expectation stated previously in the paper and the findings of several previous studies, like Bekun and Agboola (2019) and Bayer et al. (2021). The positive effect of PCGDP on CO2 emissions, in line with the reason adduced previously in the paper, is attributable to the fact that a higher level of per capita income leads to a higher level of carbon emissions due to an increased level of production and consumption in the economy. Lastly, the coefficients of urbanisation (URB) in the estimated equations are 0.117 and 0.141, with p-values of 0.000 and 0.013 respectively. Thus, URB is shown to have the expected positive effect on carbon emission, which is in line with the a priori expectation, as stated earlier in the paper, and the findings of several previous studies, like Chien et al. (2022) and Li et al. (2022).

5. Conclusions and Recommendations

This study examines the dynamic relationships between Nigeria's industrial production, financial development, and carbon emissions between 1971 and 2020 using time series data.

The debates over the relationship between financial development and industrial output as well as the conflicting theories in the literature about the connection between financial development and carbon emissions served as the basis for this study. The data's time series properties were initially investigated using the unit root tests of the Augmented Dickey-Fuller test (ADF), and the Paseran, Shin, and Smith ARDL Bounds test was then used to determine the long-term relationship between the variables. The study employed a long-run ARDL estimation technique in deriving the regression estimates, using the annual data sourced from the CBN database, the International Monetary Fund (IMF), the International Energy Agency (IEA) and World Bank's World Development Indicators.

Following the application of the aforementioned methodology, it was found that both financial development and industrial production have the expected positive effects on carbon emissions in the long run in Nigeria. In the same manner, the findings from this study showed that financial development has the expected positive effects on carbon emissions and industrial production. Consequently, it can be regarded as a major driver for industrial production and carbon emissions in Nigeria. Additionally, industrial production has the expected positive effect on carbon emissions, indicating that the level of industrialisation contributes to the emission of carbon dioxide (CO_2). It is therefore recommended that relevant authorities pursue an environment-friendly pattern of financial sector development strategies and industrialisation so as not to hamper or hinder long-run environmental sustainability. For instance, the Federal Ministry of Environment could interact with the Central Bank of Nigeria to put regulations in place for financial institutions to ensure that investment loan requests are granted after due consideration to the environmental friendliness of projects.

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