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RESEARCH PAPER

CO_2 Emission and Financial Development Nexus in Nigeria: Fresh Insights from Asymmetry Cointegration

Mansur Muhammad[a,b,*], Abubakar Isah Funtua[c], Muhammad Abdulaziz Muhammad[d], Saifullahi Sani Ibrahim[c]

a. Department of Economics, Usmanu Danfodiyo University, Sokoto, Nigeria.
b. Faculty of Economics and Business, Indonesian International Islamic University, Depok, Indonesia.
c. Department of Economics & Development Studies, Federal University Dutsin-Ma, Katsina, Nigeria.
d. Department of Business Education Kano State College of Education and Preliminary Studies, Kano, Nigeria.
* Corresponding author, E-mail: muhammad.mansur@udusok.edu.ng

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Abstract
In recent times, studies on the nexus between carbon emissions and financial development have become plentiful. Very few of them consider the nonlinearity or asymmetry of the relationship between financial development indices and CO2 emissions. The objective of this study is to explore asymmetric cointegration within the framework of the non-linear autoregressive distributed lag model on the emissions-financial development nexus using Nigeria's data from 1981 to 2020. Our findings revealed the existence of an asymmetric long-run relationship between CO2 emissions and financial development measured by credit to the private sector, financial deepening, and market capitalization. Positive shocks to Credit to private sectors have a negative and significant impact on the emission at 1% level, while negative shock is not statistically significant in explaining emission in Nigeria. Positive shocks of market capitalization insignificantly reduce emissions and vice versa. Moreover, asymmetric shocks of financial deepening have negative and significant effects on emissions in Nigeria. The study therefore recommends that domestic credits to the private sector should be geared towards enhancing renewable energy, as more investments are required especially in solar and wind energy. In addition, environmental laws be strengthened and pollution taxes be introduced to mitigate the increasing level of CO2 released through the consumption spree for energy-demanding and CO2-emitting goods aided by the increasing level of Nigeria's financial development.
Keywords: Asymmetry, CO_2 Emission, Financial Development, Market Capitalization, NARDL.
JEL Classification: C22, G00, Q5.

1. Introduction

CO2 emission arising from the unprecedented level of growth and industrialization is widely recognized as a major culprit for raising the global temperature (Acheampong, 2019; Guo, 2021). Consequences arising from emissions include but are not limited to; reduction in water bodies, toxic gas emissions, natural resource depletion, polluted air, and increased sunlight intensity (Adedoyin, Ozturk, et al., 2020; Adedoyin, Abubaka, et al., 2020). As the environment remains the only source of natural capital, conserving it remains a center core of global players (Agabo et al., 2021), hence, policy formulation strategy for mitigating global warming necessitates the curbing of CO2 emissions (Acheampong, 2019).

In the literature, several factors have been adjudged to be the reason for increased emissions such as; population expansion, economic growth, FDI, and trade (Sehrawat et al., 2011). Famous among these factors is financial system development (henceforth: FD). It is observed that, in Nigeria, as the trend of CO2 emission is increasing by almost 0.2 percent annually, financial services have been steadily improving contemporaneously (Iheanacho, 2016; Yahaya et al., 2021). This development prompts the question of whether the improvement in Nigeria's financial system is the possible cause of the increasing level of CO2.

Recently, much emphasis has been focused on the nexus between CO2 and financial system development because it is believed that, FD increases carbon emission (Zhang, 2011) via the transmission mechanism of increased energy consumption. In other words, improved financial system development is capable of increasing the energy demand in a country whose production will consequently erode environmental cleanliness. Imamoglu (2019) opined that a country's financial system development might affect negatively its environmental quality arising from higher levels of energy consumption. Yahaya et al. (2021) agree with this position as they find financial services to be detrimental to environmental quality through increasing access to consumption of high-emission technologies and appliances.

FD increases CO2 emission through many indirect channels of increased demand for energy-consuming technologies arising from both households and businesses. This effect is seen in three folds; the household, firm, and country-wide level. To the households, sound financial intermediation increases availability and access to credit which in turn increases the chances of the households to purchase energy-consuming goods such as; automobiles, washing machines, refrigerators, houses, etc. These goods according to Zhang (2011) and Guo (2021) by their nature of being high-energy-demanding products, their consumption naturally deteriorates environmental quality following the already fact that energy consumption increases CO2 emission On the second fold are the firms whose demand for machinery, and labor and fixed capital is satisfied from the money and capital markets. With improved FD, chances are that firms will increase their production through borrowings and other means of financing from both the capital and money market, hence increasing environmental consequences through increased CO2 emission.

At the macroeconomic level, the effect of FD on environmental quality when analyzed within the discourse of the transmission mechanisms of the Pollution-haven hypothesis proves to be a driver of FDI that in turn deteriorates the environmental quality of a country. The hypothesis shows how dirty industries shift to less environmentally stringent countries to enjoy high production while worrying less about environmental costs (Gill et al., 2018). In other words, FD increases the flow of FDI which in turn heightens environmental degradation.

On the flip side, is the argument of scholars that FD has positive effects on environmental quality as it lowers the level of emission (Tamazian et al., 2009; Tamazian and Bhaskara Rao, 2010; Shahbaz et al., 2013; Shahbaz et al., 2018). Amongst the arguments advanced for this, is that FD may facilitate the inflow of R&D in eco-friendly projects and lessen the cost of environmental-friendly projects (Tamazian and Bhaskara Rao, 2010). Similarly, Thangaiyarkarasi and Vanitha (2021) see the negative effect of FD on carbon emission in at least two aspects as thus; firstly, a well-developed financial system finances firms' quest for enhanced and cost-effective production technology which are devoid of environmental degradation. Secondly, improvement in FD is capable of supporting, funding, or financing various government's R&D on green and renewable energy projects. This will improve the energy infrastructure of the country as well as reduce CO_2 emissions.

From the foregoing, while it is clear that there exists a bulk of incontrovertible empirical works supporting the positive nexus between energy consumption and CO_2 emission, the same conclusion cannot be drawn for the FD-emission nexus because of the conflicting results reported herein. One plausible reason for this inconclusiveness in the results may be attributable to the model estimation techniques employed. Looking at the literature, one could see the dominant use of linear models which assume symmetrical relationships amongst variables which according to Shin et al. (2014) have the disadvantage of: poor determination of the cointegrating parameters; related insufficient information for inference and forecast; and their inability to capture some vital features of the underlying dynamics of a system (Tong, 2015).

The question to ask therefore is what if the relationship between CO_2 emission, energy demand, and FD is asymmetrical. Answering this question is the preoccupation of this work; hence, we employed the asymmetric cointegration modeling technique within a Nonlinear ARDL framework using Nigerian data.

2. Literature Review

2.1 Theoretical Underpinning

The theoretical foundations of this work will rely on the famous Environment Kuznet Curve (EKC) derived from the work of (Kuznets, 1995) on growth and inequality which is now adopted to show the nexus between the environment and the economy. The empirics arising from the EKC-backed theory point towards the fact that environmental quality deteriorates at the early stages of economic development, peaks at a turning point, and improves with a further improvement in growth thereby exhibiting an inverted U-shaped curve (Dinda, 2004; Liu et al., 2019; Ben Jebli et al., 2022).

Defined differently, the EKC shows how environmental quality changes as the fortunes of a country change (Dinda, 2004). Therefore, among the key variables in quantifying the fortunes of a country is its level of FD. An increase in FD accompanies growth, in the same way growth necessitates improved financial services. FD is therefore seen in this study as being akin to growth and is adopted as such to substitute growth in the EKC framework since it is also a variable that reveals or signifies a country's level of fortune.

Empirical findings showed increasing levels of FD deteriorating the environment via the transmission mechanism of increased demand on polluting goods and services (Zhang, 2011; Imamoglu, 2019; Yahaya et al., 2021; Guo, 2021) while some argued that it improves the environmental quality through powering domestic greening technologies (Tamazian et al., 2009; Tamazian and Bhaskara Rao, 2010; Shahbaz et al., 2013; Shahbaz et al., 2018). A cursory look at these two conflicting results, one will observe that FD harms the environment of less developed economies like Nigeria at the same time improves that of developed economies such as French (Xionga et al., 2016; Hafeez et al., 2018; Shahbaz et al., 2018). This dichotomy can be likened to the inverted U-shaped curve of the EKC hypothesis which shows both negative and positive effects of rising fortunes on the environment of a country at the initial and developed stages respectively.

Analogously, FD as a variable that is connected and seldom denotes the income level of the economy, if used, as a surrogate to growth within the context of the EKC has shown how the FD can be harmful to their environment in the initial stage of development of an economy say the less developed ones, but will turn out to mitigate environmental degradation when the economies become developed.

2.2 Empirical Review

Going through the plethora of literature, it is observed that, scholars on this subject matter have reported varying and conflicting results. For instance, Sadorsky (2010) in a panel study of 22 emerging economies, found a positive relationship between financial development and energy consumption but contrastingly, Abbasi and Riaz (2016) found that financial variables played a role in emission mitigation. It is equally observed that the reason for this difference in result sometimes arises from countries or regions being studied as seen in Xionga et al. (2016) in which, financial development was found to have reduced carbon emissions in the developed regions and increased it in the less developed regions. This conforms with the work of Hafeez et al. (2018) and Shahbaz et al. (2018) on the French economy where they argued that financial development lowers carbon emissions, thereby improving the French environmental quality.

However, the work of Imamoglu (2019) takes an exception to the developed and less developed nations dichotomy as his work conducted globally among a panel of 176 countries, found a long-run equilibrium relationship between carbon dioxide emissions and financial sector development in both the developed and developing countries.

Cetin and Ecevit (2017) also studied the impact of financial development on carbon emissions in the Turkish economy for the period 1960-2011, considering structural breaks; their study reveals a causal link between financial developments to carbon emissions. Similarly, Jiang and Ma (2019) found from a global perspective, that financial development could significantly increase carbon emissions. However, Acheampong (2019) found that none of the financial development indicators exert a significant nonlinear effect on carbon emissions, which is in tandem with Ahmed (2020) who also found a negative influence of financial effect on CO2 emissions in Egypt.

In Nigeria, the works of Adewuyi and Awodumi, (2020), Yahaya et al. (2021), and Okere et al. (2021) established empirical evidence of a positive relationship between financial development and CO2. Interestingly, Ozdeser et al. (2021) whose study used ARDL and was also conducted in Nigeria data supports the positive nexus between FD and CO2 emission through rising fossil fuel consumption. In a separate but similar study, Guo (2021) reported the same result from China following his robust Maki cointegration and frequency domain causality test.

From the literature reviewed, it is evident that there is a considerable divergence in the results obtained on the relationship between FD and environmental quality across different regions studied. In Nigeria however, there seem to be similarities in the conclusion of a positive relationship between FD and CO2 emission from the literature we have reviewed so far.

Another critical observation is that while there is a plethora of literature in this area, studies on Nigeria are scanty. Methodologically, almost all works reviewed modeled the FD-emission nexus symmetrically without exploring asymmetric regression. This has serious implications for the results obtained, the conclusion and the policy recommendations generated therefrom. Therefore, in reaction to the above, this work set out to study the asymmetric relationship between FD, energy demand, and emission in Nigeria within a NARDL framework.

3. Dataset and Econometrics Models

3.1 Dataset and Sources

Table 1 explains the data used for this study. The data is a yearly series spanning from 1981 to 2020. The choice of the period is largely explained by data availability. Before estimations, all variables are transformed into natural logarithms.

Table 1. Data Variable Measurement

S/N.	Variable	Code	Definition	Source
1	Carbon dioxide emission	$lC0_{2,t}$	This is the total carbon emission measured in thousand metric tons.	WDI
2	Domestic credit to the private sector	lcp_t	The domestic credit to the private sector by banks as a percentage of GDP.	WDI

3	Market capitalization	lmc_t	The annual market capitalization on the Nigerian stock exchange market in billions of naira.	CBN
4	Financial deepening	lfp_t	The ratio of broad money supply (m3) to nominal GDP percentage.	CBN
5	GDP	lgd_t	Economic growth	CBN

Source: World Development Indicators (2022) & Central Bank of Nigeria (2022).
Note: WDI is an acronym for World Development Indicators, while CBN stands for Central Bank of Nigeria.

3.1 Econometrics Models

In line with the objective of this study, we specify a model with CO2 as a dependent variable and domestic credit to the private sector, market capitalization, financial deepening, and GDP as regressors thus;

$$C02_t = f(lcp_t, lmc_t, lfp_t, lgd_t) \tag{1}$$

The Econometrics approach utilized in this study involves three different phases; firstly, the stationarity status of variables is examined using the traditional ADF, PP, and KPSS tests as well as the nonlinear Fourier-based unit root test of Guris (2018). The traditional test is for order of integration to ensure that none of the variables is I(2) while the latter will test the nonlinear stationarity of the variables. Secondly, we looked into the asymmetric long and short-run effect of the regressors on CO2 using the NARDL approach. In addition, an auxiliary regression for the Principal Components of FD (LCP, LMC, LFP) is conducted to see the effects, if any of the aggregated FD indices on CO2. Lastly, we conducted some important diagnostics tests for the model.

3.1.1 Non-Linear Autoregressive Distributed Lag Model

Recent developments have shown that macroeconomic variables exhibit nonlinear characteristics, as such; modeling co-integration can be done within the context of decomposed explanatory variables known as asymmetric co-integration. It is used for testing whether the positive shocks of the independent variables have the same effect as their negative shocks on the dependent variables. Although there are several methods of modeling asymmetric relationships, see Schorderet, 2003; Escribano et al., 2006; however, Shin et al. (2014) observed the dominant use of the two-step Engle-Granger technique of asymmetric co-integration. One noticeable defect of the two-step Engle-Granger technique of asymmetric cointegration is that it is not only a short-run modeling technique, but is equally less efficient than the single-step ECM estimation of Shin et al. (2014) which jointly models both the short and long-run-asymmetries-called NARDL.

Since NARDL is an extension of the Shin et al. (2001) framework, the prerequisite condition for application of ARDL to time series holds in NARDL. The major one is that the stationary status of variables shouldn't include I(2) variables. It is on this note that we conducted a unit root test on the variables using the traditional unit root tests of Augmented Dicky Fuller (ADF), Phillips- Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) after which we followed shin, Yu, and Greenwood-Nimmo (2014) to write (Equation 1) thus:

$$\begin{aligned}\Delta lC02_t \;=\; &\beta_0 + \sum_{i=0}^{m} \beta_1 \Delta lC02_{t-i} + \sum_{i=0}^{m} \beta_2 \Delta lcp_{t-i}^{+} + \sum_{i=0}^{m} \beta_3 \Delta lcp_{t-i}^{-} \\ &+ \sum_{i=0}^{m} \beta_4 \Delta lmc_{t-i}^{+} + \sum_{i=0}^{m} \beta_5 \Delta lmc_{t-i}^{-} + \sum_{i=0}^{m} \beta_6 \Delta lfp_{t-i}^{+} \\ &+ \sum_{i=0}^{m} \beta_7 \Delta lfp_{t-i}^{-} + \sum_{i=0}^{m} \beta_8 \Delta lgd_{t-i}^{+} + \sum_{i=0}^{m} \beta_9 \Delta lgd_{t-i}^{-} + \gamma_1 C02_{t-1} \\ &+ \gamma_2 lcp_{t-1}^{+} + \gamma_3 \Delta lcp_{t-1}^{-} + \gamma_4 lmc_{t-1}^{+} + \gamma_5 lmc_{t-1}^{-} + \gamma_6 lfp_{t-1}^{+} \\ &+ \gamma_7 lfp_{t-1}^{-} + \gamma_8 lgd_{t-1}^{+} + \gamma_9 lgd_{t-1}^{-} + \psi_t DU_t + \in_t\end{aligned} \qquad (2)$$

where Δ is the difference operator indicating the first difference of variable, i is the lagged values, $\beta_1\ to\ \beta_9$ and $\gamma_1\ to\ \gamma_9$ are the short run and long run coefficients respectively, ψ_t is the coefficient of break date dummy $\in_t$ is the disturbance term. The error correction equation of NARDL formulated above can be expressed as;

$$\Delta lC02_t \;=\; \beta_0 + \textstyle\sum_{i=0}^{m} \beta_1 \Delta lC02_{t-i} + \sum_{i=0}^{m} \beta_2 \Delta lcp_{t-i}^{+} + \sum_{i=0}^{m} \beta_3 \Delta lcp_{t-i}^{-} + \sum_{i=0}^{m} \beta_4 \Delta lmc_{t-i}^{+} + \sum_{i=0}^{m} \beta_5 \Delta lmc_{t-i}^{-} + \sum_{i=0}^{m} \beta_6 \Delta lfp_{t-i}^{+} + \sum_{i=0}^{m} \beta_7 \Delta lfp_{t-i}^{-} + \sum_{i=0}^{m} \beta_8 \Delta lgd_{t-i}^{+} + \sum_{i=0}^{m} \beta_9 \Delta lgd_{t-i}^{-} + \vartheta_t ect_{t-1} + \in_t \qquad (3)$$

4. Result Interpretation and Discussion

4.1 Descriptive Statistics and Correlation Matrix

Table 2 presents at a glance the salient characteristics of the 40 observations of the annual time series data we used in the study as well as pair-wise correlations between the variables. The results show that a positive and significant correlation exists between the dependent variable LCO2 and the four independent variables of LCP, LFI, LFP, and LGD. All results of the pairwise correlation range from 0.65 to 0.95.

Table 2. Descriptive Statistics and Pair-wise Correlations

	LCO2	LCP	LMC	LFP	LGD
Mean	11.3508	2.1554	6.2136	2.6680	10.3882
Std. Dev.	0.2371	0.3523	3.1508	0.3321	0.52524
Min.	10.6558	1.5989	1.6094	2.1358	9.6934
Max.	11.8101	2.9757	10.5607	3.2146	11.1857
JB	0.9393	1.7447	3.9087	3.8964	4.1977
Probability	0.6252	0.4179	0.1416	0.1425	0.1225
Observations	40	40	40	40	40
LCO2	1.0000				
LCP	0.6509	1.0000			
LMC	0.8427	0.8403	1.0000		
LFP	0.7186	0.7186	0.7872	1.0000	
LGD	0.8496	0.8289	0.9581	0.8884	1.0000

Source: Research finding.

4.2 Unit Root Test

In carrying out the NARDL asymmetric cointegeration technique, variables can be I(0) or I(1) but cannot be integrated into the second order I(2). Hence, a unit root is conducted following the traditional methods of ADF, PP and KPSS, and results obtained therefrom, affirm that, all variables are I(1) except for a few exceptions reported from KPSS which identifies the stationarity of LCO2 and LFP at level. Notwithstanding, the non-existence of any 1(2) variables validates the adoption of the NARDL and the mixed levels of integration further encourages the deployment of the NARDL estimation technique.

Table 3. Stationarity Test Results

Variables	ADF		PP		KPSS	
	level	1st diff.	level	1st diff.	level	1st diff.
LCO2	-1.6157	-9.7153**	-1.1779	-15.276**	0.7301*	
LCP	-1.7343	-5.8011**	-1.5853	-9.9767**	0.6649	0.5000*
LMC	-0.4914	-4.7595**	-0.5002	-4.7797**	0.7555	0.1422**
LFP	-0.9609	-5.7717**	-0.8372	-6.1641**	0.6424*	
LGD	-1.0411	-3.7830**	0.4510	-3.7830**	0.7348	0.292293**

Source: Research finding.

Note: **&* shows 5% and 1% level of significance.

However, testing for order of integration as far as nonlinear models are concerned cannot suffice because Güriş (2018) mentioned that, the traditional unit root tests tend to be nonstationary when dealing with nonlinear variables. To avert this problem, the new flexible Fourier form nonlinear unit root test proposed by Güriş (2018) in which the nonlinear adjustment is modeled using an exponential smooth threshold autoregressive (ESTAR) model is deployed to test whether the variables are nonlinear stationary or not.

Table 4. Guris (2018) Nonlinear Unit Root Test

Variables	Lags	Test statistics	Decision	Critical values K=1	
LCO2	3	16.22887**	Stationary	1%	20.32
LCP	3	7.293370	Nonlinear unit root	5%	14.72
LFP	3	12.88887*	Stationary	10%	12.32
LMC	3	18.65670**	Stationary		
LGD	3	18.42112**	Stationary		

Source: Research finding.
Note: the signs of ***, **, and * refer to the rejection of the unit root hypothesis at 1%, 5%, and 10% levels respectively. Lag method (AIC), Maximum lags(3).

From the Guris (2018) nonlinear unit root test, evidence shows that except credit to the private sector that depicts unit root, all other variables are stationary with nonlinearity with breaks at unknown dates at a 5% level of significance.

4.3 Short and Long-run NARDL Results

Consequent upon the validation of the suitability of NARDL by the unit test results seen in Tables 3 and 4, we carried out the short-run and long-run NARDL estimation with the view of exploring the impact of credit on private sector, financial deepening, market capitalization as well as growth on the level of CO2 emission in Nigeria.

Table 5. Short and Long-run NARDL Results

NARDL Short-Run Result; Dependent Variable: LCO2							
Regressors	Lags						
	0	1					
Δ LCP^{+}	0.206396	0.435727					
	(0.3398)	(0.0966)***					
Δ LFP^{+}	0.777132	-1.247151					
	(0.0260)**	(0.0018)*					
Δ LFP^{-}	-0.501581	-0.629001					
	(0.2439)	(0.0418)**					
Δ LGD^{+}	0.341742	-2.245438					
	(0.7203)	(0.0048)*					
NARDL Long-Run Result							
LCP^{+}	LCP^{-}	LMC^{+}	LMC^{-}	LFP^{+}	LFP^{-}	LGD^{+}	LGD^{-}
-0.1486	-0.2138	-0.3177	2.0970	-0.8193	-0.3856	7.4869	9.6556
(0.0010)*	(0.7696)	(0.3055)	(0.0757)***	(0.0004)*	(0.0673)***	(0.1124)	(0.0967)***
Diagnostics							
Bound test	ECM_{t-1}	Adj. R^2	Hetero. Test	LM Test			
4.155510	-0.863618	0.739170	(0.1280)	(0.1277)			
	(0.0000)*						
LCP_{LR}	LMC_{LR}	LFP_{LR}	LGD_{LR}				
25.18963	14.77864	17.56625	5.79223				
(0.0000)	(0.0006)	(0.0002)	(0.0161)				

Source: Research finding.

Note: ( ) = Probability values, LR=Long-run Wald test. *, **, *** mean significance at 1%, 5%, and 10%, respectively.

Table 5 reports the results obtained from the estimation of Equation (2). In the short run, the result shows that while the positive shock of LCP in the current period is positive but statistically insignificant, a 1% increase in LCP from last year will induce emission by 0.40% in the current period of the short run. In other words, credit to the private sector granted in the current period may have a positive influence on the level of emission but will only be significant after a year. This is plausible in the sense that as credit is extended to households and firms, which enables them to procure CO2-emitting products such as automobiles and machinery, there is a lag period in the process of purchase, shipping, and installation before subsequently put into usage, which will increase CO2 emission. Similarly, a positive shock in financial deepening in Nigeria in the current year will exacerbate LCO2 emission by 0.77 whereas that of the previous year will reduce emission at a much higher rate of 1.24 in the short run. Interestingly, shock from LFP^{-} in the previous year is seen to be a contributing factor to LCO2 emission in the current period. Lastly, the lag of positive growth will reduce emissions.

From the long-run result, a shock in LCP^{+} will reduce emission by 0.21. Although this is not expected a priori, the result may be pointing to the possibility that the increased credit access by households and firms is channeled towards procurement of environmentally friendly products or those powered by renewable energies. This result conforms with the result of (Tamazian et al., 2009; Tamazian and Bhaskara Rao, 2010; Shahbaz et al., 2018) conducted in BRICS, Transitional economies, and France in respective order.

While a positive shock in market capitalization is not seen to have a positive effect on emission as expected a priori, a negative shock reduces emission by 2.09. This is because a negative shock in market capitalization means a shrink in the firm's value which directly harms its productive capacity. A decrease in production will certainly reduce CO2 emission - this is expected a priori. The positive and negative shocks of financial deepening (LFP) are 0.81 and 0.38 reduction and increase in CO2 respectively. An increase in financial deepening (here defined as a ratio of money supply concerning the GDP) means more money in circulation, hence more effective demand from agents amongst which are environmentally-degrading products. Lastly, a negative shock in GDP causes a decline in CO2 emission by 9.65, because a decline in GDP anthropogenic consequences of production.

On the whole, the long-run Wald test of the regressors affirms the nonlinear asymmetries in our model. Also, our dynamic multipliers graphs (Figures 3 to 5) show that the dependent variable responds more to negative shocks than positive shocks of the regressors except LFP.

In general, financial development is seen to be a contributing factor to the reduction of CO2 emissions in Nigeria. This finding is not a stand-alone as Hafeez et al. (2018), and Shahbaz et al. (2018) reported it for 52 countries and the French economy in respective order. Notwithstanding, the finding is bizarre in the context of the Nigerian economy because it is at par with the reports of Adewuyi and Awodumi (2020), Yahaya et al. (2021), and Okere et al. (2021) all conducted in Nigeria. The reason for this may not be far from the difference in the methodology employed. While in the aforementioned works estimation was conducted based on the assumption of a symmetrical relationship, in our case we assumed that the positive and negative effects of the regressors on CO2 are rather asymmetric. The dynamic multipliers graphs derived therefrom support this position as they reveal how CO2 responds more to negative shocks than positive shocks.

The post-estimation results reveal that: the bound test affirms the cointegration of variables which means there is evidence of long-run relationship among the variables; The adjusted R^2 of 0.73 supports model fitness; the ECM is negative, less than unity and statistically significant and could revert any disequilibrium shock experienced at a speed of 86%; the probability values of (0.1280) and (0.1277) for Heteroskedasticity test and Breusch-Godfrey serial correlation (LM Test) show that the errors in the residuals of the model are homoscedastic and the model is also devoid of serial correlation. The CUSUM and CUSUM squares test reveal that the parameters of the model are stable.

Additionally, it is acknowledged in the literature that several studies do conduct a Principal Component Analysis (PCA) for the three financial development variables of LCP, LFP, and LMC to see the aggregated effect of financial development on CO2 emission. Therefore, a PCA for the three financial development variables of LFI, LFP, and LMC is carried out and the variable derived therefrom is called FD. Below is the table for the PCA.

Table 5. PCA Result

Variable	Eigen Value	Proportion	Cumulative Proportion
LCP	2.643761	0.8813	0.8813
LFP	0.212850	0.0710	0.9522
LMC	0.143389	0.0478	1.0000

Source: Research finding.

From Table 5 above, the Eigenvalues and proportions of 2.64 and 0.88 for LCP show the variables' dominance in the LCP. However, notwithstanding, the two other variables of LFP and LMC form the 12% other component of the PCA variable generated. Following this, Table 6 below shows the NARDL result of the PC of FD.

Table 6. NARDL Results of Aggregated FD and LCO2

NARDL Long-Run Result Dependent Variable: LCO2				
FD^+	FD^-		LGD	
-0.0339	-0.1611		-0.3267	
(0.3939)	(0.0007)*		(0.3785)	
Diagnostics				
Bound test	ECM_{t-1}	Adj. R^2	Heteroskedasticity test	LM Test
5.9422	-0.9179 (0.0000)*	0.5757	(0.8095)	(0.5445)

Source: Research finding.

Note: ( ) = Probability values, * means significance at 1%. LED=energy demand.

A positive shock from FD is not statistically significant, but a negative one will induce LCO2 emission by 0.16. Evidence from the result shows that LGD has no long-run asymmetric effect on LCO2. This is understandable in the sense that LED is the transmission mechanism through which the impact of FD is passed on LCO2, as access to credit spurred by FD increases demand for carbon-emitting products such as automobiles and machinery for households and firms respectively.

5. Conclusion and Policy Recommendation

Several studies have been conducted on the impact of financial development and the quantum of CO2 emission in several countries across different regions of the globe. However, except a very few, all works assumed symmetric and linearity in the relationship among variables. In this work, we explored the possibility of a nonlinear relationship with the assumption of asymmetric cointegration within the NARDL for Nigeria from 1981 to 2020. Findings reveal that financial development is a contributing factor to the reduction of CO2 emissions in Nigeria during the period under study. This finding agrees with Hafeez et al. (2018) and Shahbaz et al. (2018) conducted on the French economy, but is at variance with those works on the Nigerian economy by Adewuyi and Awodumi, (2020), Yahaya et al. (2021), and Okere et al. (2021). The reason for this may not be far from the difference in the methodology employed. While we employed the nonlinear asymmetric cointegration technique of NARDL, they employed a linear and assumed symmetrical relationship. Our results about the existence of the asymmetric relationship between CO2 and financial development measured by credit to the private sector, financial deepening, and market capitalization. CO2 emission is found to be more responsive to negative shocks of credit to private and market capitalization than it is to positive shocks. Contrariwise is the case for financial deepening.

This revelation of CO2 is more responsive to negativity than positive shocks to FD variables, and linear models do not account for it, therefore, it means that symmetrical models have ignored this very important part of the discussion in the CO2-FD nexus, the inclusion of which herein appears to be a value addition.

Based on the findings emanating from this study, we believe that the following suggestion will cushion the asymmetric effect of financial development on carbon emissions in Nigeria. First, domestic credits to the private sector should be geared towards enhancing renewable energy, as more investments are required especially in solar and wind energy. Second, a well-developed financial system is a panacea for green energy finance, policy directions that make credit available at zero or low interest rates should be pursued for the renewable energy market to reduce the use of unclean energy.

References

Abbasi, F., & Riaz, K. (2016). CO2 Emissions and Financial Development in an Emerging Economy: An Augmented VAR Approach. *Energy Policy*, *90*, 102-114. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0301421515302305

Abid, M. (2016). Impact of Economic, Financial, and Institutional Factors on CO2 Emissions: Evidence from Sub-Saharan Africa Economies. *Utilities Policy*, *30*, 1-10. Retrieved from https://www.academia.edu/download/99103710/Impact_of_economic_financial_and_institutional_factors_on_CO2.pdf

Abokyi, E., Appiah-Konadu, P., Abokyi, F., & Oteng-Abayie, E. F. (2019). Industrial Growth and Emissions of CO2 in Ghana: The Role of Financial Development and Fossil Fuel Consumption. *Energy Reports*, *5*, 1339-1353.Retrieved from https://www.sciencedirect.com/science/article/pii/S2352484719302859

Acheampong, A. O. (2019). Modeling for Insight : Does Financial Development Improve Environmental Quality? *Energy Economics*, *83*, 156-179, Retrieved from https://doi.org/10.1016/j.eneco.2019.06.025

Adewuyi, A. O., & Awodumi, O. B. (2020). Environmental Pollution, Energy Resource Import, Economic Growth, and Financial Development: Theoretical Exploration and Empirical Evidence from Nigeria. *International Journal of Environmental Science and Natural Resource*, *26*, 022-031. Retrieved from https://www.researchgate.net

Adedoyin, F., Abubakar, I., Victor, F., & Asumadu, S. (2020). Generation of Energy and Environmental-Economic Growth Consequences : is there any Difference across Transition Economies? *Energy Reports*, *6*, 1418-1427, Retrieved from Retrieved from https://doi.org/10.1016/j.egyr.2020.05.026

Adedoyin, F., Ozturk, I., Abubakar, I., Kumeka, T., & Folarin, O. (2020). Structural Breaks in CO2 Emissions : are they Caused by Climate Change Protests or other Factors? *Journal of Environmental Management*, *266*, 110628, Retrieved from https://doi.org/10.1016/j.jenvman.2020.110628

Agabo, T., Abubakar, I. F., & Adedoyin, F. F. (2021). The Anthropogenic Consequences of Energy Consumption and Population Expansion in Africa? Do Governance Factors Make Any Difference? *Environmental Science and Pollution Research*, *2020*, Retrieved from https://doi.org/10.1007/s11356-020-12280-z

Ahmed, F. M., Hadi, D. M., & Ahmed, A. K. (2020). The Impact of Economic Growth, Financial Development, and Trade Openness on Environmental Degradation in Egypt. *Polytechnic Journal*, *10*(1), 98-102. Retrieved from https://polytechnic-journal.epu.edu.iq/cgi/viewcontent.cgi?article=1544&context=home

Akif Destek, M., & Sarkodie, S. A. (2019). Investigation of Environmental Kuznets Curve for Ecological Footprint: The Role of Energy and Financial Development. *Science of the Total Environment*, *650*, 2483–2489. Retrieved from https://mpra.ub.uni-muenchen.de/106881/1/MPRA_paper_106881.pdf

Authors, F. (2011). Management of Environmental Quality: An International Journal Article information. Retrieved from https://www.emeraldgrouppublishing.com/journal/meq

Ben Jebli, M., Madaleno, M., & Schneider, N., & Shahzad, U. (2022). What does the EKC Theory Leave Behind? A State-of-the-Art Review and Assessment of Export Diversification-Augmented Models. *Environmental Monitoring and Assessment*, *194*(6), 414. Retrieved from https://link.springer.com/content/pdf/10.1007/s10661-022-10037-4.pdf

Birnintsaba, D. A., Ozdeser., H., & Saliminezhad, A. (2021). Impact Analysis on The Effective Synergy between Climate Change, Ecological Degradation and Energy Consumption on Economic Growth in Nigeria. *SAGE Open*, *11*(4), 1-20. Retrieved from https://journals.sagepub.com/doi/pdf/10.1177/21582440211061361

Çetin, M., & Ecevit, E. (2017). The Impact of Financial Development on Carbon Emissions under the Structural Breaks: Empirical Evidence from Turkish Economy. *International Journal of Economic Perspectives*, *11*(1), 64-78. Retrieved from https://www.researchgate.net

Chow, G. C., & Lin, A. L. (1971). Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series. *The Review of Economics and Statistics, 53*(4), 372-375. Retrieved from https://www.jstor.org/stable/

Dinda, S. (2004). Environmental Kuznets Curve hypothesis: A survey. *Ecological Economics, 49*(4), 431–455. Retrieved from https://doi.org/10.1016/j.ecolecon.2004.02.011

Escribano, A., Sipols, A. E., & Aparicio, F. (2006). Nonlinear Cointegration and Nonlinear Error Correction: Record Counting Cointegration Tests. *Communications in Statistics: Simulation and Computation*, *35*(4), 939–956, Retrieved from https://doi.org/10.1080/03610910600880351

Gill, F. L., Kuperan Viswanathan, K., Zaini, M., & Karim, A. (2018). The Critical Review of the Pollution Haven Hypothesis. *International Journal of Energy Economics and Policy*|, *8*(1), 167–174, Retrieved from http:www.econjournals.com

Guo, Y. (2021). Financial Development and Carbon Emissions: Analyzing the Role of Financial Risk, Renewable Energy Electricity, and Human Capital for China. *Discrete Dynamics in Nature and Society*, *2021*, Retrieved from https://doi.org/10.1155/2021/1025669

Hafeez, M., Chunhui, Y., Strohmaier, D., Ahmed, M., & Jie, L. (2018). Does Finance Affect Environmental Degradation: Evidence from One Belt and One Road Initiative Region. *Environmental Science and Pollution Research*, 25, 9579-9592. Retrieved from https://link.springer.com/article/10.1007/s11356-018-1317-7

Iheanacho, E. (2016). The Impact of Financial Development on Economic Growth in Nigeria: An ARDL Analysis. *Economies*, *4*(4), 1-12, Retrieved from https://doi.org/10.3390/economies4040026

Imamoglu, H. (2019). The Role of Financial Sector in Energy Demand and Climate Changes: Evidence From the Developed and Developing Countries. *Environmental Science and Pollution Research*, *26*(22), 22794–22811, Retrieved from https://doi.org/10.1007/s11356-019-05499-y

Jiang, C., & Ma, X. (2019). The Impact of Financial Development on Carbon Emissions: A Global Perspective. *Sustainability, 11*, 5241, Retrieved from https://doi.org/10.3390/su11195241.

Johansen, S., & Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration with Appucations to the Demand for Money. *Oxford Bulletin of Economics and Statistics, 52*(2), 169-210. Retrieved from https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x

Kuznets, S. (1995). Economic Growth and Inequality. *Quarterly Journal of Economics, 110*(2), 353-377. Retrieved from https://doi.org/10.2307/2118443

Ohajionu, U. C., Gyamfi, B. A., Haseki, M. I., & Bekun, F. V. (2021). Assessing the Linkage between Energy Consumption, Financial Development, Tourism, and Environment: Evidence from Method of Moment's Quantile Regression. *Environmental Science and Pollution Research,* Retrieved from https://doi.org/10.1007/s11356-021-17920-6

Okere, K. I., Ogbulu, O. M., Onuoha, F. C., & Ogbodo, I. (2021). What drives The Energy Consumption Mix in Nigeria? The Role of Financial Development, Population Age Groups, Urbanization and International Trade: Insight from ARDL Analysis. *OPEC Energy Review, 45*(2), 161-190. Retrieved from https://doi.org/10.1111/opec.12193

Okoye, L. U., Omankhanlen, A. E., Okoh, J. I., Okorie, U. E., Ezeji, F. N., Ehikioya, B. I., & Ezu, G. K. (2021). Effect of Energy Utilization and Financial Development on Economic Growth in Nigeria. *International Journal of Energy Economics and Policy, 11*(2), 392-401. Retrieved from https://doi.org/10.32479/ijeep.10691

Ozdeser, H., Somoye, O. A., & Seraj, M. (2021). The Impact of Financial Development on Energy Consumption in Nigeria. *OPEC Energy Review, 45*(2), 240-256. Retrieved from https://doi.org/10.1111/opec.12198

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics, 16*(3), 289-326. Retrieved from https://doi.org/10.1002/jae.616

Pesaran, H. H., & Shin, Y. (1998). Generalized Impulse Response Analysis in Linear Multivariate Models. *Economics Letters, 58*(1), 17-29. Retrieved from https://doi.org/10.1016/s0165-1765(97)00214-0

Sadorsky, P. (2010). The Impact of Financial Development on Energy Consumption in Emerging Economies. *Energy Policy*, *38*(2010), 2528–2535. Retrieved from https://doi.org/10.1016/j.enpol.2009.12.048

Safi, A. Chen, Y., Wahab, S., Ali, S., Yi, X., & Imran, M. (2021). Financial Instability and Consumption-Based Carbon Emission in E-7 Countries: The Role of Trade and Economic Growth. *Sustainable Production and Consumption, 27*(2021), 383‑391. Retrieved from https://doi.org/10.1016/j.spc.2020.10.034

Ghosh, S., & Kanjilal, K. (2014). Long-term Equilibrium Relationship between Urbanization, Energy Consumption, and Economic Activity: Empirical Evidence from India. *Energy*, *66*, 324-331. Retrieved from https://doi.org/10.1016/j.energy.2013.12.052

Schorderet, Y. (2003). Asymmetric Cointegration. Retrieved from https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=f51d466e122ab63eb491f3aed0787bdbe382ceff

Shahbaz, M., Kumar Tiwari, A., & Nasir, M. (2013). The Effects of Financial Development, Economic Growth, Coal Consumption and Trade Openness on Co2 Emissions in South Africa. *Energy Policy*, *61*, 1452-1459. Retrieved from https://doi.org/10.1016/j.enpol.2013.07.006

Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental Degradation in France: The Effects of FDI, Financial Development, and Energy Innovations. *Energy Economics*, *74*, 843-857. Retrieved from https://doi.org/10.1016/j.eneco.2018.07.020

Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2012). Modeling Asymmetric Cointegration and Dynamic Multipliers in a Nonlinear ARDL Framework. *SSRN Electronic Journal*, 1–44. Retrieved from https://doi.org/10.2139/ssrn.1807745

Tamazian, A., & Bhaskara Rao, B. (2010). Do economic, financial, and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energy Economics*, *32*(1), 137–145. Retrieved from https://doi.org/10.1016/j.eneco.2009.04.004

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy Policy*, *37*(1), 246–253. Retrieved from https://doi.org/10.1016/j.enpol.2008.08.025

Thangaiyarkarasi, N., & Vanitha, S. (2021). The Impact of Financial Development on Decarbonization Factors of Carbon Emissions: A Global Perspective. *International Journal of Energy Economics and Policy*, *11*(6), 353–364. Retrieved from https://doi.org/10.32479/ijeep.11872

Tong, H. (2015). *Nonlinear Time Series Analysis*. Retrieved from https://encyclopediaofmath.org/images/8/87/Nonlinear_time_series_analysis.pdf

Xionga, L., Tub, Z., & Jub, L. (2016). Reconciling Regional Differences in Financial Development and Carbon Emissions: A Dynamic Panel Data Approach. *Energy Procedia*, 2989–2995. Retrieved from https://10.25156/ptj.v10n1y2020.pp98-102

Yahaya, N. S., Ado, M. B., & Datti, M. I. (2021). Financial Development and CO2 Discharge in Nigeria. *Journal of Research in Emerging Markets*, *3*(3), 51-59. Retrieved from https://doi.org/10.30585/jrems.v3i3.652

Zhang, Y. J. (2011). The Impact of Financial Development on Carbon Emissions: An Empirical Analysis in China. *Energy Policy*, *39*(4), 2197-2203, Retrieved from https://doi.org/10.1016/j.enpol.2011.02.026

Appendix

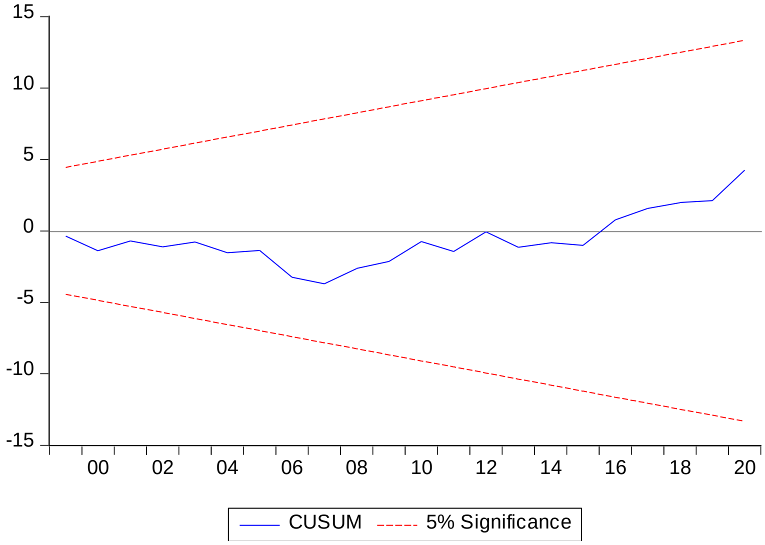

Figure 1. CUSUM Test for CO2-FD Nexus in Nigeria

Source: Research finding.

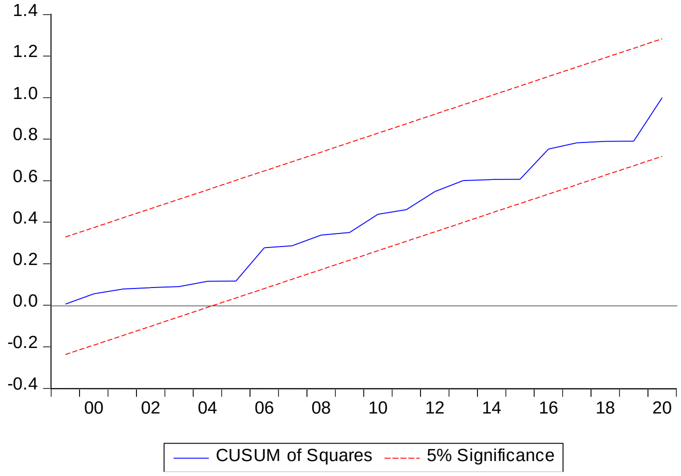

Figure 2. CUSUM of Squares Test for CO2-FD Nexus in Nigeria

Source: Research finding.

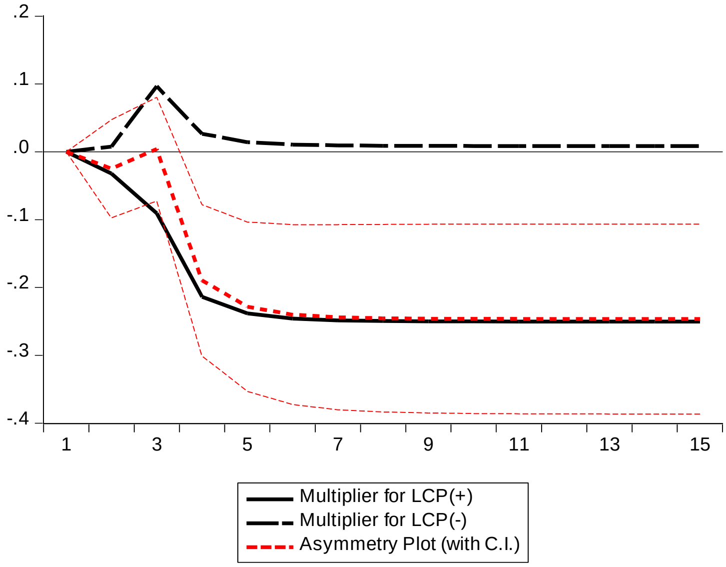

Figure 3. Dynamic Multiplier for LCP

Source: Research finding.

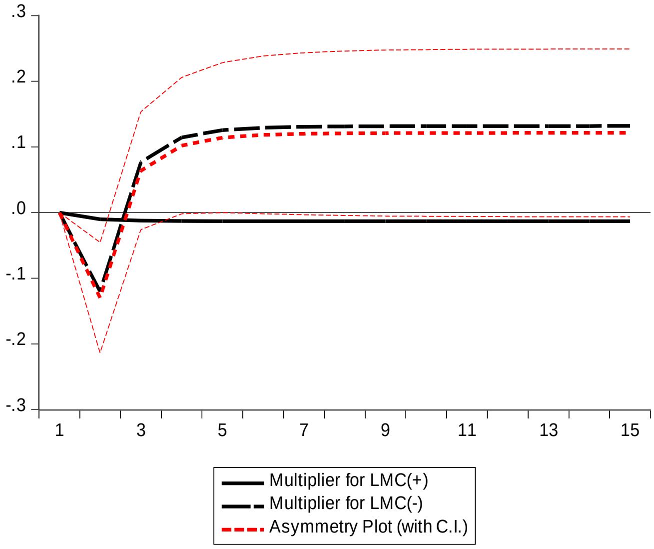

Figure 4. Dynamic Multiplier for LMC

Source: Research finding.

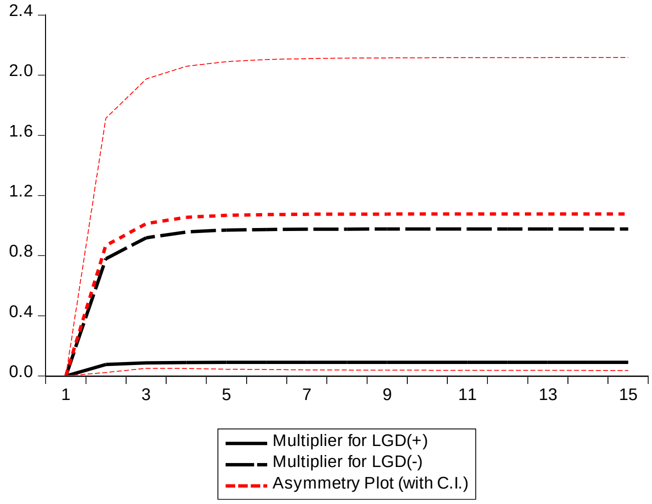

Figure 5. Dynamic Multiplier for LGD
Source: Research finding.

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