



# The Effect of Lending Rate on Carbon Emissions in Nigeria

Anthony Enisan Akinlo\* & Sikiru Adetona Adedokun

1. Department of Economics, Obafemi Awolowo University, Ile-Ife, Nigeria

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**Abstract:** Most previous studies on financial development and carbon emissions have typically omitted the role of lending rate, thereby creating a knowledge gap in literature. The study therefore provides a new insight into how financial development impact carbon emissions with emphasis on lending rates. Specifically, we examine the direct effect of lending rates on carbon emissions using fully modified ordinary least squares and probe the possible symmetric effect using the nonlinear autoregressive distributed lag model. The results from fully modified OLS show that lending rate reduces carbon emissions. The nonlinear ARDL results confirm symmetry in the short-run and asymmetry in the long-run. The results show that lending rate reduces carbon emissions. Credit to the private sector-GDP ratio and energy intensity improve environmental quality in the short run but increases carbon emissions in the long run. An increase in per capita income leads to an increase in carbon emissions, while urbanization and trade openness reduce them. Essentially, policymakers need to consider the issues of nonlinearity in the formulation of lending rate policies that will assist in reducing pollution in Nigeria. In particular, optimal lending rate must be attained, while promoting the adoption of efficient and environmentally friendly technologies that will facilitate attainment of the same or even higher output level coupled with a reduction in carbon emissions in the long run.

**Keywords:** Lending rate, carbon emissions, FMOLS, Asymmetry, Nigeria

**JEL classification:** C24, F21, Q52, Q56

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## INTRODUCTION

Since Karanfil (2009) suggested the incorporation of financial variables into the energy model, the relationship between finance and environmental quality has received exceptional prominence in energy economics and energy policy implementations. This development can be attributed to the argument in the literature that increased financial development tends to facilitate higher loan disbursement with lower financing costs for their customers. The increased availability of loans assists the firms in creating demand for output, thereby leading to increased production in the economy. Meanwhile, increased domestic production entails increased commercial energy consumption, which in turn leads to increased pollution and environmental degradation (Zafar et al. 2019, Pan et al. 2019, Hao et al. 2020).

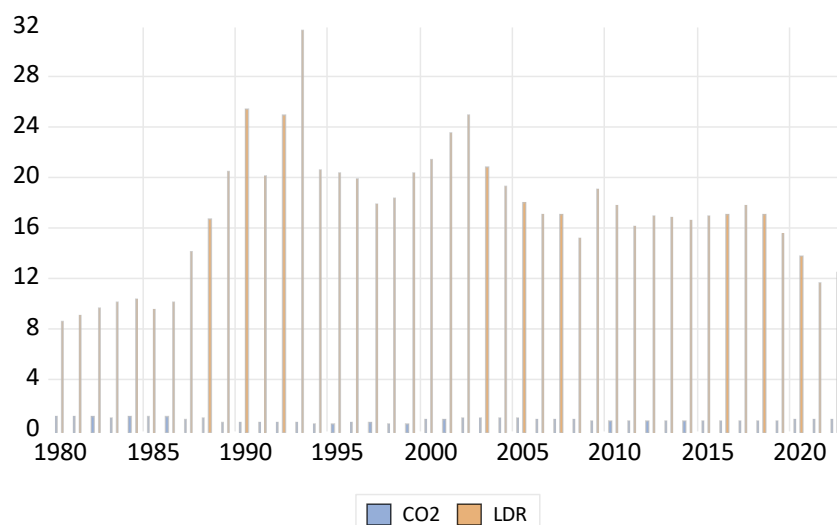
However, there is a counterargument that financial development can improve the quality of the environment (Khan and Orturk 2021, Salahuddin et al. 2015). It is contended that improved financial development and intermediation can help reduce financing costs, freeing more funds for environmentally friendly projects. Besides, increased financial development could encourage energy generation from alternative and cleaner sources, thus leading to a reduction in pollution (Tamazian et al. 2009).

Generally, one thing is clear from the existing literature: there is yet no consensus on the effect of financial development on carbon emissions. Hence, the need for further empirical studies. Aside from that, none of the known empirical studies except Broni et al. (2020) has examined the impact of lending rates on carbon emissions. Finally, no study has investigated the asymmetric effect of lending rate on carbon emissions. These are gaps that our study attempts to fill. Hence, objectives of this study are two folds. One examines effect of the lending rate on carbon emissions taking into cognizance the mediatory roles of income, credit to the private sector and energy use. Two, investigates the asymmetric effect of lending rates on carbon emissions.

The rest of the paper is organized as follows: Section 2 provides an overview of the lending rate and carbon emissions in Nigeria over the period 1980 to 2022. Section 3 presents the literature review, while section 4 presents the data and methodology. Section 5 contains the results and discussions, and finally, the conclusion constitutes Section 6.

### **LENDING RATE AND CARBON EMISSIONS IN NIGERIA: AN OVERVIEW**

The trends of carbon emissions and the lending in Nigeria over the period 1980 to 2022 is shown in Fig. 1. The quantity of carbon emissions in 1980 was 0.92 million metric tons but declined to 0.75 million metric tons in 1983. It, however, increased to 0.86 million metric tons in 1986. The quantity of carbon emissions decelerated from 0.67 million metric tons in 1987 to 0.34 million metric tons in 1999. The trend assumed an upward trajectory from 2000 through 2005. It dropped marginally from 2006 through 2009. The level of carbon emissions was stable at approximately 0.6 over the period 2010 to 2022. The relatively high level of carbon emissions in Nigeria can be attributed to increased oil production and the policy of gas flaring. Moreover, increased economic activities arising from increased oil revenue are a factor behind increased carbon emissions in Nigeria. The increased income from oil facilitated easy availability of credit to firms, assisting in creating high demand for their services, leading to increased industrialization. This development led to increased energy consumption that deteriorated environmental quality through increased air pollution.



**Figure 1: Pie chart of carbon emissions (CO<sub>2</sub>) and Lending rate in Nigeria, 1980-2022.**

In 1980, the lending rate was 8.4 percent. It increased steadily over the years, reaching a peak of 31.6 per cent in 1993. The rate dropped to 20.5 per cent in 1994 and maintained a downward trend till 1998, standing at 18.2 per cent. It assumed an upward trend from 1999 at 20.3 per cent, reaching a peak of 24.8 per cent in 2002. The figure decelerated from 20.7 per cent in 2003 to 15.1 per cent in 2008, only to increase to 19.0 per cent in 2009. Lending rates maintain a relatively stable level of approximately 16.7 per cent over the period 2010 and 2019. It, however, fell sharply between 2020 and 2022 with an average of 12.5 per cent.

## **LITERATURE REVIEW**

### **Theoretical Issues**

Theoretically, two perspectives are discernible on the effect of financial development on carbon emissions nexus. The first perspective argues that financial development leads to higher emissions rates. The argument is that a developed and efficient financial system assists in reducing the adverse effects of asymmetric information, which in turn lowers the financing cost of firms. Consequently, firms are aided to achieve economies of scale through investment in new production and heavy equipment, thereby hurting the environment through increased pollution. Besides, where improved financial systems lead to increased consumer credit, consumption of durable goods is likely to be boosted with adverse effects on the environment (Bui, 2020). Likewise, in a situation where economic growth is boosted through well-developed and efficient financial systems, production and consumption are likely to increase, and thus pollution. However, there is an alternative view that says financial development can help reduce carbon emissions. It is argued that improved financial intermediation by reducing financial costs can assist firms in funding more environmentally friendly projects. Moreover, financial development can assist in carbon trading activities that could help to mitigate emissions of harmful air pollution (Tamazian et al. 2009). Finally, financial development could foster efficient resource allocation and mobilization of financial resources to firms to support the acquisition of energy-efficient technologies. With respect to the effect of lending rate and carbon emissions, two perspectives are noted in the literature. The first perspective argues that lending rates can assist in reducing carbon emissions. The lending rate is the cost of borrowing in the economy, and when it is low, the financing costs will be positively affected. Low financing costs, in turn, could assist firms in channeling more resources into environmentally friendly projects. Moreover, a low lending rate that enhances firms' access to adequate funds could aid the acquisition of the right technology and machinery that are environmentally friendly. Besides, a lending rate that causes financing costs to be reduced could yield economies of scale for firms through investing in new production lines and machinery, thereby leading to a reduction in pollution. The second perspective opines that the lending rate can lead to increases in carbon emissions. Specifically, a high lending rate that constrains firms' access to funds could the firms to use outdated technology and machinery that causes excessive pollution.

### **Empirical Literature**

On the empirical side, many studies have examined the effect of financial development on carbon emissions with divergent results depending on the methodology adopted, the

countries investigated, and the time frame. Generally, while some found that financial development lowers carbon emissions (Godil et al. 2020, Wang et al. 2023, Kahouli et al. 2022, Mukhtarov et al. 2024), few others reported that financial development increases carbon emissions, thereby hurting the environment (Majeed et al. 2020, Omoke et al. 2020, Baydoun and Aga 2021, Brown et al. 2022, Bilgili et al 2025). Yet, a constituent of the literature found evidence in support of nonlinearity between financial development and carbon emissions (Chaudhry et al. 2022, Akinlo and Apanisile 2023).

The literature on the effect of lending rate on carbon emissions is nascent. In fact, the only known study on the link between financial development and carbon emissions is Broni et al. 2020 in the USA. Clearly, though literature on the financial development-carbon emissions is growing, the effect of lending rate on carbon emissions has been ignored. As a fact no known study has explored the possible asymmetric effect of lending rate on carbon emissions. These are gaps that need to be filled in literature. In short, the relationship between lending rate and carbon emissions is an empirical issue. The only known study on the subject matter by Broni et al (2020) found that the impact of lending rate on carbon emissions depends on prevailing economic and socio-political conditions. However, one major issue not addressed by Broni et al. (2020) is the asymmetric effect of the lending rate on carbon emissions. Incorporation of asymmetry is critical since a negative or a positive change in lending rate might not have the same effect on carbon emissions. Hence, aside from the paucity of studies on the effect of lending rate on carbon emissions, there is a need to ascertain the asymmetric effects of the lending rate on carbon emissions in Nigeria.

## METHODOLOGY

### Data

The study utilizes annual time series data from 1980 to 2022 for the estimation of the model. The variables employed in our analysis are carbon emissions (lCO<sub>2</sub>), lending rate (lldr), trade openness (top), ratio of private sector credit to GDP (lcre), energy intensity growth (lteng), per capita income (lpci), oil price (loip), population density (lpde), urbanization (lurb), per capita income squared (lpci<sup>2</sup>), and interaction variables, namely the product of lending rate and per capita income (lldr\*lpci), product of lending rate and ratio of private sector credit to GDP (lldr\*lcre), and the product of lending rate and energy intensity growth (lldr\*lteng). Table 1 shows the definitions and sources of the variables.

**Table 1: Definition of variables and sources of data**

Variables	Definition of variables and sources of data
lcre	credit to the private sector. Source: CBN Statistical Bulletin (2023)
loip	price of oil (US\$ per barrel). Source: BP Statistical Review of World Energy (2023)
lteng	energy intensity growth. Source: World Development Indicators (2023)
lurb	urbanization. Source: CBN Statistical Bulletin (2023 Edition)
lCO <sub>2</sub>	carbon emissions (millions metric tons). Source: World Development Indicators(2023).
lpci	per capita income.
ltop	trade openness. Export plus imports over GDP
lldr	lending rate. CBN Statistical Bulletin (2023) Edition
lpde	population density



$$lldr_t^+ = \sum_{j=1}^m \Delta lldr_j^+ = \sum_{j=1}^m \max(\Delta lldr_j, 0)$$

$$lldr_t^- = \sum_{j=1}^m \Delta lldr_j^- = \sum_{j=1}^m \min(\Delta lldr_j, 0) \dots \dots \dots (6)$$

Following Shin et al. (2014), if we substitute equation (6) into (5), we obtain a nonlinear ARDL (NARDL) given as in (7):

where  $(lldr^+, lldr^-)$  are the positive and negative partial sums as defined in equation 6, while  $n, m, x, r, y,$  and  $s$  are lag orders. From equation 7, asymmetry of changes in  $lldr$  in the long run is verified using the Wald test. The null hypothesis is stated as  $(\lambda_2^+ = \lambda_3^-)$ . The long-run impact of positive change in  $lldr$  ( $lldr^+$ ) is obtained as  $B^+ = -(\lambda_2^+/\lambda_1)$ , while the negative changes in  $lldr$  ( $lldr^-$ ) on  $Co_2$  emissions is given as  $B^- = -(\lambda_3^-/\lambda_1)$ . For short run asymmetry of  $lldr$ , we employ the Wald test with the null hypothesis stated as  $(\beta_6^+ = \beta_6^-)$ .

Next, we utilize the NARDL model as specified in equation (7) to obtain the dynamic multipliers  $m_h^+$  and  $m_h^-$ , where  $m_h^+$  is for the change in  $lldr_t^+$  while  $m_h^-$  relates to the change in  $lldr_t^-$ :

$$m_h^+ = \sum_{i=0}^h \frac{\partial CO_2_{t+i}}{\partial lldr_{t-1}^+}, m_h^- = \sum_{i=0}^h \frac{\partial CO_2_{t+i}}{\partial lldr_{t-1}^-} \quad h = 0, 1, 2 \dots \dots \dots (8)$$

Note that as  $h \rightarrow \infty, m_h^+ \rightarrow \beta^+,$  and  $m_h^- \rightarrow \beta^-$

## EMPIRICAL RESULTS AND DISCUSSION

### Descriptive Statistics

Tables 2 and 3 give the summary statistics and correlation analysis of the variables. From Table 2, the mean values of the variables are positive over the sample period, indicating a positive trend for all the variables. Also, the standard deviation of each underlying variable is less than its mean value except credit to the private sector. This indicates stable variations among the variables over the study period.

**Table 2: Descriptive statistics**

Variable	lCO <sub>2</sub>	lldr	ltop	lcre	lteng	lpci	loip	lurb
Mean	0.605	17.363	52.306	5767.824	682.639	31581.8	41.426	36.224
Standard Deviation	0.170	4.929	12.616	8864.30	85.933	42209.87	28.742	8.822
Minimum	0.326	8.40	9.14	8.08	333.973	137.59	12.28	22.00
Maximum	0.928	31.60	53.28	29030.01	798.973	129397.0	109.45	52.00

### Correlation Analysis

Table 3 shows the pairwise correlation matrix of the variables. One, none of the independent variables has a coefficient of correlation of each of the variables is less than 0.6, meaning

that the possibility of multicollinearity between the dependent and independent variables is low. Two, all the independent variables are negatively correlated with the dependent variable, namely carbon emissions.

**Table 3: Spearman Rank Correlation.**

Variable	Ico2	lldr	ltop	lcre	lteng	lpci	loip	lurb
ICO <sub>2</sub>	1.000							
lldr	-0.586	1.000						
ltop	-0.251	0.461	1.000					
lcre	-0.280	0.113	0.244	1.000				
lteng	-0.389	0.213	0.361	0.653	1.000			
lpci	-0.279	0.111	0.253	0.999	0.661	1.000		
loip	-0.232	-0.378	0.163	0.659	0.434	0.663	1.000	
lurb	-0.278	0.108	0.248	0.999	0.654	0.999	0.661	1.000

### Results of the Unit Root Tests

The results of the Augmented Dickey Fuller (ADF), (Dickey and Fuller 1981) and Phillips Perron (PP) (Phillips and Perron 1988) unit root tests to determine the stationarity of the variables are presented in Table 4. For ADF, all the variables are stationary at the first difference. However, for PP test, trade openness is stationary at level, while other variables are stationary at first difference. Since the variables are stationary at first difference, we applied the Johansen-Juselius (1990) test to investigate the cointegration relationship between lending rate and carbon emissions.

**Table 4: Unit Root Tests**

	ADF		PP	
	Level	First Difference	Level	First Difference
ICO <sub>2</sub>	-2.095	-4.211***	-2.149	-6.261***
lldr	-2.258	-4.597***	-2.258	-6.079***
ltop	-1.863	-4.801***	-2.400**	-8.104***
lcre	-1.056	-3.832***	-0.331	-4.648***
lteng	-2.242	-3.231**	-2.271	-7.356**
lpci	-1.686	-3.049***	-1.182	-2.944***
loip	0.904	-4.988***	-0.942	-6.234***
lurb	-1.771	-5.147**	-2.088	-8.883***

**Table 5: Co-interpretation Results (including constant) r is the number of co-interpretation rating vectors.**

Null	Alternative R	$\lambda - Max$	CV (95%)	Trace	C.V(95%)
0	1	43.851	40.078	105.261	95.754
$\leq 1$	2	29.273	33.877	61.409	69.819
$\leq 2$	3	17.378	27.584	32.136	47.856
$\leq 3$	4	7.410	21.132	14.758	29.797
$\leq 4$	5	6.300	14.265	7.349	15.495
$\leq 5$	6	1.048	3.841	1.048	3.841

The outcomes as shown in Table 5 confirm only one cointegration among the variables using the trace and  $\lambda$ -max tests. This means that there is long run relationship among carbon emissions, lending rate, ratio of credit to the private sector to GDP, energy use, trade openness and per capita income.

### The Results of FMOLS

Next, to know the effect of lending rate on carbon emissions, equations (3) and (4) are estimated using the Fully Modified OLS technique. The results are presented in Table 6. Columns 1-4 are results where interaction terms are not included, while interaction terms are included in columns 5-6. Our results show that the lending rate reduces carbon emissions in all the columns, but is significant only in columns 1, 5, and 6. In column 1, without interaction, a 1% increase in the lending rate reduces carbon emissions by 0.17%. However, in columns 5 and 6 with interaction variables, a 1% increase in lending rate reduces carbon emissions by 3.73% and 3.63%, respectively. The finding that the lending rate reduces carbon emissions is consistent with the results of Broni et al. (2020) for the USA. The following factors might explain our finding that the lending rate reduces carbon emissions. Firstly, a higher lending rate might have caused the cost of capital to move up, which might have precipitated a fall in production and output. In this case, energy consumption and the associated discharge of greenhouse gases might be reduced because of this scale effect. Besides, only individuals and firms in good financial standing can borrow at high interest rates. In this case, domestic firms might not be able to operate at full capacity, which may occasion a reduction in carbon emissions. Moreover, a high lending rate might have forced small and medium-sized enterprises responsible for producing large volumes of pollution into the environment out of business, thereby reducing pollution (Glackin, 2002). Finally, because of a high lending rate, financial institutions might respond to higher credit risks by intentionally reallocating loans away from high-emit firms toward low-carbon sectors.

In columns 5 and 6, where the interaction terms are incorporated, the impact of the lending rate on carbon emissions remains negative. The essence of the inclusion of the interactive terms is to know the overall impact of the lending rate under the conditions of increasing financial development, energy use and income growth respectively. Both  $lldr*lcre$  and  $lldr*pci$  have significant impact on carbon emissions. However, the coefficient of  $lldr*lteng$  is not significant. The coefficient of  $lldr*lcre$  is negative, while  $lldr*lpci$  is positive. The negative effect exhibited by  $lldr*lcre$  may be because higher financial development promotes the transition to cleaner technology, as against merely encouraging the scale of carbon-intensive production. In essence, the interaction of lending rate and the ratio of the credit to the private sector to GDP serves as means for green investments through various channels. These channels include increased credit that leads to investment in renewable energy infrastructure and increased competition and efficiency. The positive impact of the lending rate and per capita income shows that growth mediates a positive relationship between the lending rate and carbon emissions. This suggests that the positive impact of the ratio of credit to private sector to GDP offset the negative the negative impact of the lending rate on carbon emissions. This development possibly suggests that in the period of increased economic growth, coupled with production expansion, emissions and waste, and all economic agents endeavour to meet their obligations, increasing lending rate becomes more burdensome for them. In the circumstance, economic agents might be constrained to

neglect good environmental practices, as this might be the only rational option to adopt, leading to increased pollution.

**Table 6: FMOLS**

Var	1	2	3	4	5	6
C	-0.368 (-0.210)	1.255 (0.702)	-0.931 (0.563)	-2.768* (-1.684)	5.192 (1.359)	-4.648 (-0.239)
lco2 <sub>t-1</sub>	0.824*** (12.339)	0.813*** (11.804)	0.759*** (10.933)	0.460*** (5.007)	0.412*** (5.672)	0.492*** (5.570)
lldr	-0.172* (-1.758)	-0.124 (-1.181)	-0.101 (-0.932)	-0.014 (-0.136)	-3.733*** (-3.324)	-3.634*** (-3.507)
ltop	-0.008 (-0.113)	0.030 (0.478)	-0.069 (0.957)	-0.118* (-1.647)	-0.051 (-0.914)	-0.042 (-0.751)
lcre	-0.140* (-1.753)	-0.142 (-1.483)	-0.181** (-2.278)	-0.256*** (-3.273)	1.921** (1.994)	1.721* (1.772)
lteng	-0.010 (-0.110)	0.055 (0.585)	-0.024 (-0.290)	-0.077 (-0.941)	-0.226** (-2.875)	-0.230 (-0.227)
lpci	0.170* (1.883)		0.205** (2.331)	0.253*** (3.048)	-2.793** (-2.571)	-2.594** (-2.412)
lpci <sup>2</sup>		0.011 (1.582)				
loip			0.062 (1.221)	0.091* (1.888)	0.089** (2.460)	0.089** (2.330)
lpde				-0.018 (-0.589)	0.006 (0.2510)	0.008 (0.330)
lurb				-0.702*** (-4.458)	-0.690*** (-4.970)	-0.687*** (-4.941)
lldr*lcre					-0.725 (-2.212)	-0.656** (-1.983)
lldr*lpci					1.015** (2.731)	0.946** (2.579)
lldr*lteng						-0.003 (-0.008)
R <sup>2</sup>	0.692	0.686	0.690	0.739	0.780	0.771

Note: In parenthesis are the t-values. \*\*\*, \*\* and \* denote significant at 1%, 5% and 10%, respectively

With respect to other main variables, trade openness is negatively related to carbon emissions except in column 2. This finding implies that trade openness improves the environmental quality in Nigeria. The result is consistent with the findings of Zhang et al. (2017). The ratio of credit to private to GDP has mixed results. In columns 1-4 without interaction terms, the relationship between the ratio of credit to the private sector to GDP and carbon emissions is negative and significant. This implies that financial development (measured as the ratio of private sector credit to GDP) reduces carbon emissions. This finding aligned with the results of Yuxiang and Chen (2011) and Jalil and Feridun (2011) but contradicts the findings of Zhang (2011) and Tamazian and Bhaskara (2010). For columns 5-6 with interaction terms, the credit to the private sector-GDP ratio is positive and significantly related to CO<sub>2</sub> emissions, except in column 6, where it is negative.

The results show an insignificant negative relationship between energy use and CO<sub>2</sub> emissions, except in columns 5 and 6, with interaction terms, where the coefficient is

significant. This might suggest the adoption of efficient and environmentally friendly technology in the country. This result is consistent with the result of Saidu et al. (2020) for Nigeria. While the oil price shows a significant positive relationship with carbon emissions, the association between urbanization is negative and significant. Population density has no significant effect on carbon emissions. Per capita income has a significant positive effect on CO<sub>2</sub> emissions in columns 1-4 without interaction terms. However, it becomes negative and significant in models with interaction variables except in column 6, where it is negative. The finding that per capita income, on its own, increases carbon emissions may indicate that economic growth leads to increased production, which in turn precipitates increased pollution. This finding aligned with Menyah and Wolde-Rufael (2010), Saidu et al. 2020, and Patel and Mehta (2023).

### Results of Nonlinear ARDL

The results of the nonlinear ARDL estimation\* are presented in Table 7. The results support the acceptance of the alternative hypothesis in the long run, meaning that CO<sub>2</sub> responds differently to both increases and decreases in the lending rate. The Wald test stands at 7.242 and is statistically significant at the 5% level. In the short run, however, we accept the null hypothesis, meaning that increases and decreases in the lending rate produce an equal effect on carbon emissions in the short-run period. Specifically, the Wald test is 1.6 and is statistically insignificant, thus confirming that there is no asymmetric effect for lending rate in the short run.

**Table 7: NARDL Estimation Results**

Dependent variable: $ICO_2$			
Variable	Coefficient	t-statistics	p-value
Constant	17.336*	2.159	0.083
$ICO_{2,t-1}$	-0.557***	-3.324	0.021
$lldr_t^+$	-2.268*	-2.190	0.080
$lldr_t^-$	4.620**	2.832	0.037
$ltop_{t-1}$	0.391	1.503	0.193
$lcre_{t-1}$	0.313	1.028	0.351
$ltentg_{t-1}$	1.560***	3.681	0.014
$lpci_{t-1}$	1.894	1.828	0.127
$\Delta lldr_t^+$	0.931	0.645	0.548
$\Delta lldr_{t-1}^+$	3.873	1.811	0.130
$\Delta lldr_{t-2}^+$	-0.351	-0.551	0.606
$\Delta lldr_{t-3}^+$	-0.807	-1.218	0.277
$\Delta lldr_t^-$	0.650	1.740	0.142
$\Delta lldr_{t-1}^-$	-2.696**	-2.490	0.055
$\Delta lldr_{t-2}^-$	0.258	0.426	0.688
$\Delta lldr_{t-3}^-$	-0.654	-1.450	0.207

\* It needs to be pointed out that the preliminary exercises, namely the unit root test and bounds test. The unit root test confirmed that no I(2) variable is involved, while the bounds test confirmed cointegration in the nonlinear ARDL and nonlinear ARDL with imposed short-run symmetry (see the results in Appendix 1).

$\Delta ltop_t$	-0.030	-0.215	0.838
$\Delta ltop_{t-1}$	-0.694	-1.717	0.147
$\Delta ltop_{t-2}$	-0.660*	-2.338	0.067
$\Delta ltop_{t-3}$	-0.311*	-2.092	0.091
$\Delta lcre_t$	0.380*	2.425	0.060
$\Delta lcre_{t-1}$	-1.348*	-2.305	0.069
$\Delta lcre_{t-2}$	-1.283**	-2.753	0.040
$\Delta lentg_t$	0.527	1.224	0.276
$\Delta lentg_{t-1}$	-1.888***	-5.177	0.004
$\Delta lentg_{t-2}$	0.730	0.664	0.536
$\Delta lentg_{t-3}$	5.137	1.703	0.149
$\Delta lpci_t$	2.637**	2.448	0.058
$\Delta lpci_{t-1}$	0.743	1.129	0.310
$\Delta lpci_{t-2}$	-0.248	-0.446	0.674
$\Delta lpci_{t-3}$	2.235	1.727	0.145
Long run (LR) asymmetric coefficient		Long and Short run symmetry tests	
$LR_{eow}^+ = -4.074^{**} (0.024)$		$W_{LR,eow} = 7.242^{**}(0.043)$	
$LR_{eow}^- = 8.298^{**} (0.025)$		$W_{SR,eow} = 1.600 (0.490)$	
Statistics and diagnostic tests			
$X_{Norm}^2 = 0.945 (0.623)$		$X_{Het}^2 = 1.076 (0.524)$	
$X_{SC}^2 = 3.832 (0.149)$		$X_{FF}^2 = 0.213 (0.819)$	

\*, \*\*, and \*\*\*, indicate significance level for 10%, 5%, and 1%, respectively.  $W_{LR}$ , are  $W_{SR}$  are the Wald test for the null of long and short-run symmetry, respectively  $x_{SC}^2$ ,  $x_{NORM}^2$ ,  $x_{HET}^2$  and  $x_{FF}^2$  symbolize the LM test for serial correlation, normality, functional form, and heteroscedasticity, respectively.

The results reveal that the asymmetry in the effect of lending rate on carbon emissions is a long-run phenomenon in Nigeria. Consequently, to model the dynamic interaction between the lending rate and carbon emissions appropriately, one should adopt a nonlinear ARDL, which allows for long-run asymmetry with short-run symmetry.

Taking cognizance of this, we re-estimate equation (7), imposing short-run symmetry with only long-run asymmetries. The results are presented in Table 8. The results show that the long-run equilibrium of carbon emissions behaviour is explained by the lagged value of carbon emissions, lending rate, trade openness, ratio of credit to the private sector to GDP, and energy intensity growth. On the other hand, the short-run dynamics of carbon emissions are explained by lagged values of trade openness, the ratio of credit to the private sector to GDP, the lagged value of energy use growth, the lending rate, and per capita income. The outcomes provide evidence of significant symmetric short-run dynamics and long-run asymmetric effects of lending rate shocks.

The coefficient of positive (upward movement in lending rate) partial sums of lending rate (ldr+) is negative and significant at 1% level, while that of the negative (downward movement in lending rate) partial sums decompositions (ldr-) is positive and significant at 5% level. The results show that an increase in the lending rate will reduce carbon emissions. Likewise, a reduction in the lending rate will reduce carbon emissions.

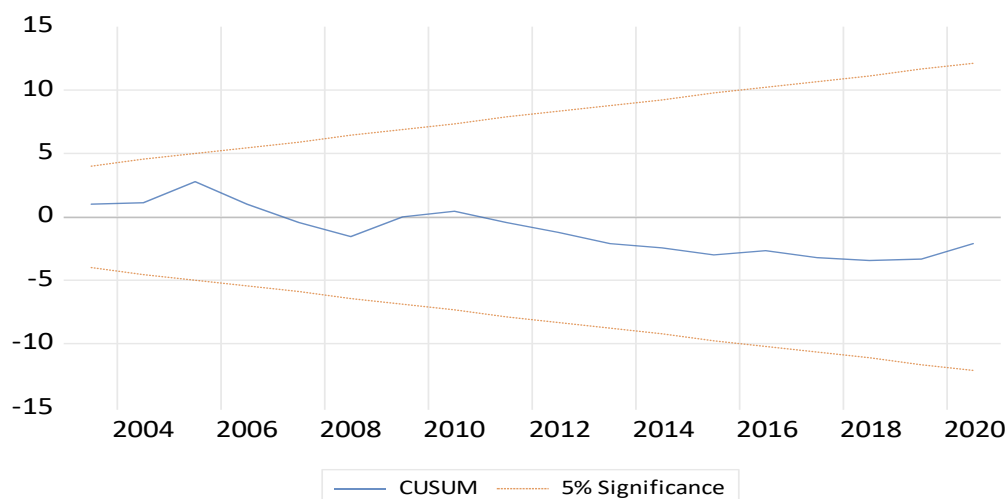
The long-run coefficients of positive ( $lldr^+$ ) and negative ( $lldr^-$ ) changes in the lending rate are 2.159 and 2.077, respectively. This indicates that a 1 per cent increase in lending rate causes a 2.158 per cent reduction in carbon emissions. In the same way, a 1 per cent decrease in lending rate causes a 2.077 per cent reduction in carbon emissions. This shows that the positive effect exceeds the negative effect.

**Table 8: NARDL Estimation with only long-run asymmetries**

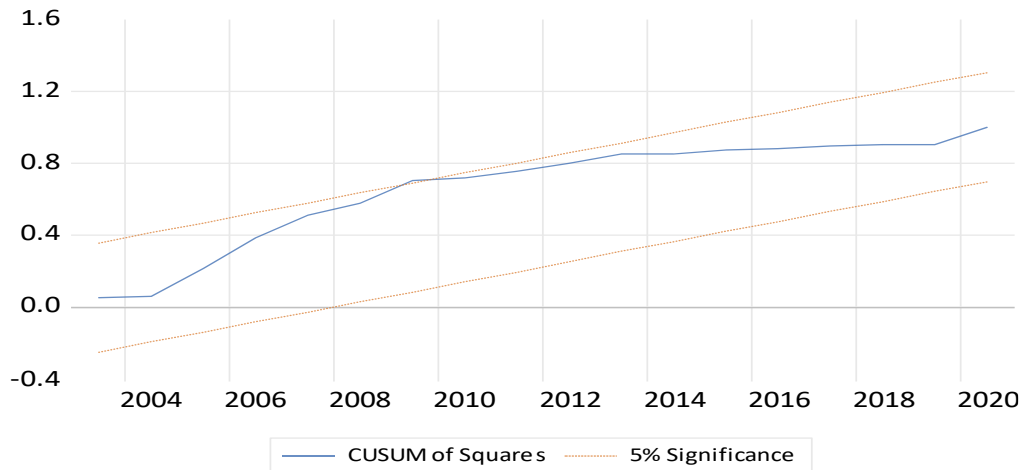
Dependent variable: $lCO_2$			
Variable	Coefficient	t-statistics	p-value
Constant	20.131**	2.564	0.024
$lCO_{2,t-1}$	-0.936***	-3.996	0.002
$lldr_{t-1}^+$	2.020***	-2.954	0.011
$lldr_{t-1}^-$	1.944**	2.532	0.025
$ltop_{t-1}$	0.401**	2.171	0.042
$lcre_{t-1}$	0.551*	1.899	0.080
$leng_{t-1}$	1.408***	3.044	0.009
$lpci_{t-1}$	0.654	1.725	0.108
$\Delta ltop_t$	0.042	0.312	0.760
$\Delta ltop_{t-1}$	-0.011	-0.847	0.413
$\Delta ltop_{t-2}$	-0.534***	-3.312	0.006
$\Delta ltop_{t-3}$	-0.468***	-3.284	0.006
$\Delta lcre_t$	0.066	0.328	0.748
$\Delta lcre_{t-1}$	-0.572**	-2.423	0.031
$\Delta lcre_{t-2}$	-0.363*	-1.837	0.089
$\Delta lcre_{t-3}$	-0.605**	-2.776	0.016
$\Delta leng_t$	-0.282	-1.567	0.141
$\Delta leng_{t-1}$	-2.253***	-3.691	0.003
$\Delta leng_{t-2}$	-1.017	-1.440	0.174
$\Delta lpci_t$	2.259***	3.156	0.008
$\Delta lpci_{t-1}$	0.215	0.516	0.614
$\Delta lpci_{t-2}$	-0.417	-0.996	0.337
$\Delta lpci_{t-3}$	0.594	1.272	0.226
$\Delta lldr_t$	-0.603**	-2.411	0.031
Long run (LR) asymmetric coefficient		Long run symmetry tests	
$LR_{lldr}^+ = -2.158^{***} (0.0000)$		$W_{LR, eow} = 8.074^{***} (0.004)$	
$LR_{lldr}^- = 2.077^{***} (0.0042)$			
Statistics and diagnostic tests			
$X_{Norm}^2 = 0.504 (0.777)$		$X_{Het}^2 = 2.316 (0.059)$	
$X_{SC}^2 = 3.916 (0.044)$		$X_{FF}^2 = 3.543 (0.065)$	

\*, \*\*, and \*\*\*, indicate significance level for 10%, 5%, and 1%, respectively.  $W_{LR}$ , and  $W_{SR}$  are the Wald test for the null of long and short-run symmetry, respectively.  $x_{SC}^2$ ,  $x_{NORM}^2$ ,  $x_{HET}^2$  and  $x_{FF}^2$  symbolize the LM test for serial correlation, normality, functional form, and heteroscedasticity, respectively.

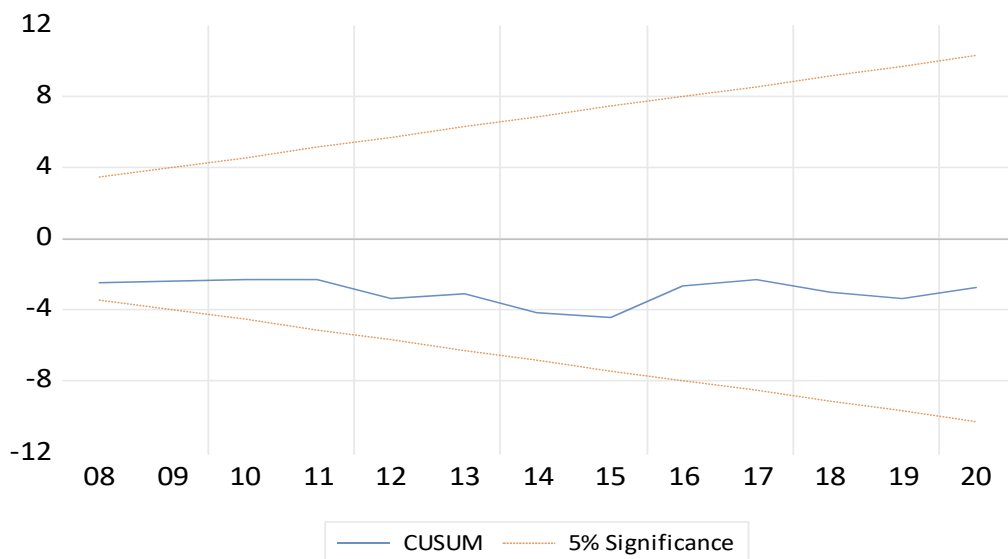
Trade openness has a significant positive effect on carbon emissions in the long run, but a significant negative effect in the short run. What this finding suggests is that an increase in lending rate initially reduces carbon emissions because of a reduction in production and energy consumption; however, in the long run, carbon emissions increase as investment in cleaner, energy-efficient technologies is discouraged. In this case, firms are compelled to rely on older, dirtier equipment. The coefficient of the ratio of private sector credit to GDP is positive and significant in the long run, but negative and significant in the short run. In the short run, an increase in the ratio of credit to the private sector to GDP, otherwise called financial deepening, allows firms to enjoy increased efficiency and technological upgrade. However, in the long run, financial deepening increases carbon emissions due to the scale effects of industrial expansion and increased energy consumption. The coefficient of energy is positive and significant in the long run, but negative in the short run, especially in the first lag. This finding suggests that an increase in energy use reduces carbon emissions in the short run, which arises from efficiency gains and adoption of cleaner, energy-efficiency technologies. In the long run, however, increased economic growth and infrastructure upgrades eventually outpaced the short-run efficiency gains, leading to increased carbon emissions. Per capita income has a positive in both the short and long run in line with a priori expectations. This should not come as a surprise because higher income directly boosts consumption, industrial production, and energy use. Finally, the coefficient of the lending rate is negative and significant in the short run, supporting the long-run result. The diagnostic tests for the estimated model (restricted and unrestricted) are presented in the lower part of Tables 7 and 8. The results show that the residuals of the estimated models pass all the diagnostic tests, meaning that the models are well-specified. The cumulative (CUSUM) and cumulative sum of squares (CUSUMQ) tests confirm stability except for the CUSUMQ for the restricted model, which shows some degree of instability at early years. The results are shown in figures 2 and 3 for the model without restriction and figures 4 and 5 for the model with restriction.



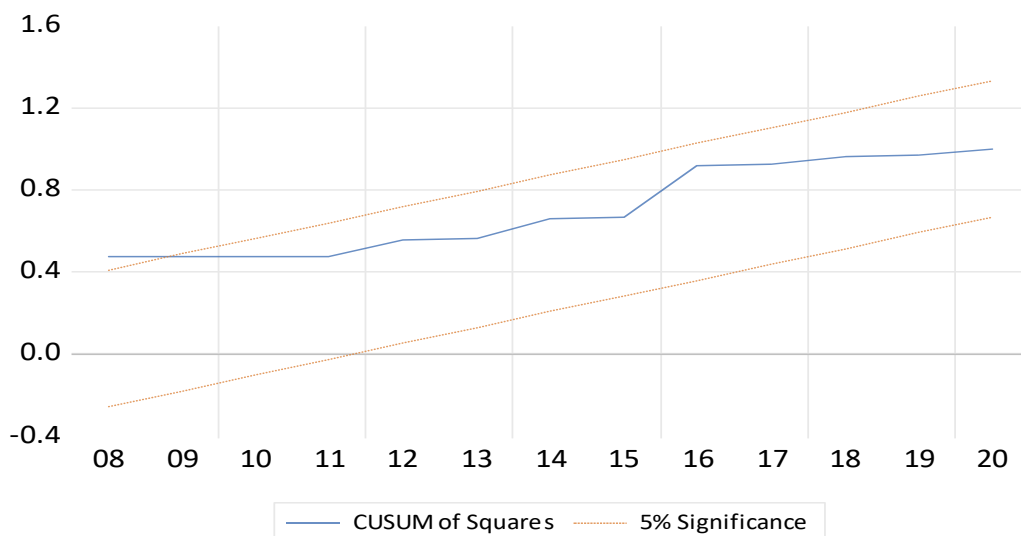
**Figure 2:** Plot of CUSUM test for nonlinear ARDL model without restriction.



**Figure 3:** Plot of CUSUMQ test for nonlinear ARDL model without restriction

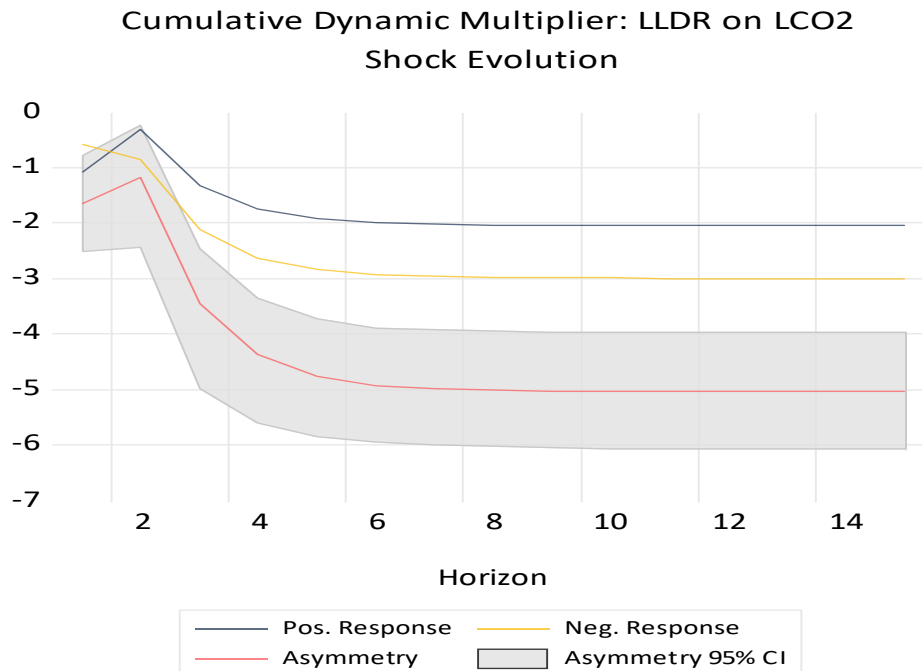


**Figure 4:** Plot of CUSUM test for nonlinear ARDL model with restriction.

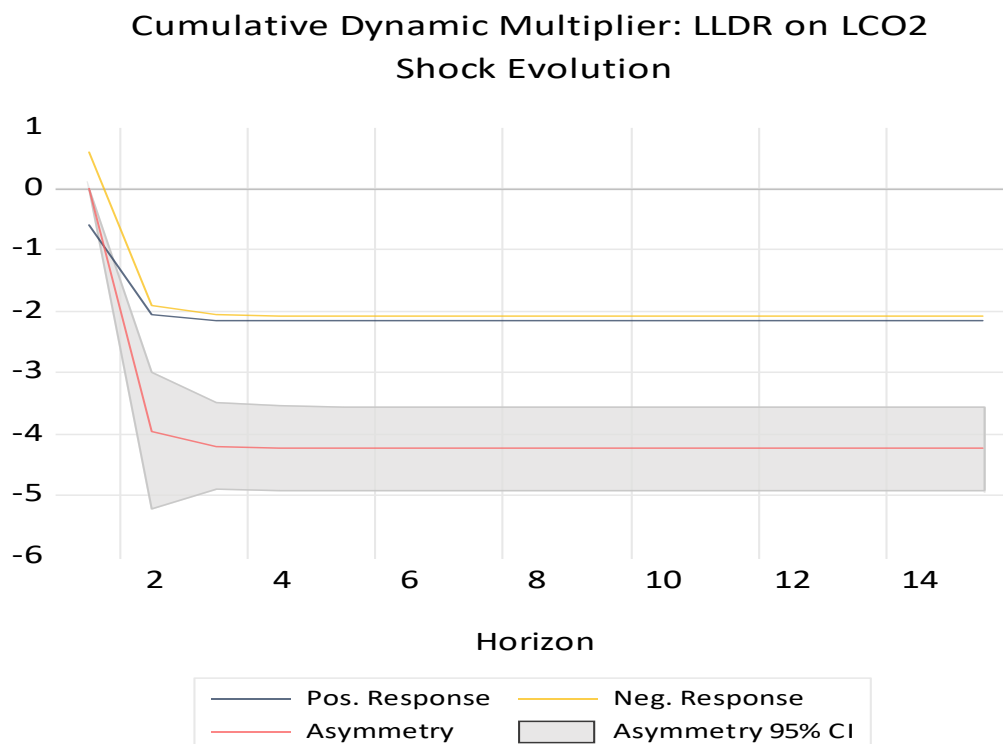


**Figure 5:** Plot of CUSUMQ test for nonlinear ARDL model with restriction.

To investigate the patterns of dynamic asymmetric adjustments of carbon emissions from its initial equilibrium to the new steady state in the long run after a shock, the study employs Shin et al.'s (2014) dynamic multipliers. The dynamic effects are revealed in figures 6 and 7 for models without restriction and with restriction, respectively. The continuous blue line indicates the positive shock, while the orange line represents the negative shock.



**Figure 6:** Plot of Cumulative Dynamic Multiplier for the nonlinear ARDL model without restriction



**Figure 7:** Plot of Cumulative Dynamic Multiplier for the nonlinear ARDL model with restriction

The lines show how a 1 per cent positive/negative shocks on the lending rate affect carbon emissions. The two lines show the asymmetric adjustment to positive and negative shocks at a given forecast. The asymmetric curve, which is a linear combination of dynamic multipliers associated with positive and negative shocks, is plotted together with its lower and upper bounds at the 95% confidence interval. The dynamic multipliers computed from the nonlinear ARDL for two models show evidence of non-linear adjustment of carbon emissions to lending rate shocks. These dynamics reveal that emissions respond more rapidly to a decrease in the lending rate as compared to an increase in the lending rate.

## CONCLUSIONS

Although the literature on the relationship between financial development and carbon emissions is growing, the effect of lending rate on carbon emissions has been ignored. Aside from that, in the literature, no study has investigated the asymmetric effect of lending rate on carbon emissions. Hence, the main objective of this study is first to examine the effect of the lending rate on carbon emissions, and second, to ascertain whether the relationship is asymmetric or symmetric in the case of Nigeria.

The study employed annual time series data for Nigeria covering 1980-2022, applying standard econometric techniques, fully modified OLS, and a nonlinear ARDL model to arrive at the following findings. One, the cointegration test confirms cointegration among carbon emissions, lending rate, energy use, ratio of credit to the private sector to GDP, per capita income, and trade openness. This means that there is a long-run relationship among the variables.

The FMOLS results show that the lending rate, on its own, reduces carbon emissions. The results show that the interaction of per capita income and lending rate increases carbon emissions, while the interaction of the ratio of credit to the private sector to GDP and lending rate reduces carbon emissions. Results from the nonlinear ARDL confirm short-run symmetry and long-run asymmetry on the relationship between lending rate and carbon emissions. While the coefficient of positive partial sums of lending rate ( $ldr+$ ) is negative and significant at 1% level, the negative partial sums decomposition ( $ldr-$ ) is positive and significant at 5% level. The results show that an increase in the lending rate will reduce carbon emissions. Likewise, a reduction in the lending rate will reduce carbon emissions.

Based on these findings, the following policy inferences are drawn. Since evidence from the nonlinear ARDL confirmed short-run symmetry and long-run asymmetry, it suggests that the most appropriate way to model the dynamic interactions between lending rate and carbon emissions is nonlinear ARDL, which allows for both short-run symmetry and long-run asymmetry. Moreover, given that the lending rate reduces carbon emissions in the short and long run, policymakers should ensure that an optimal lending rate is achieved in the country. This is pertinent because lending rates above the optimal to improve environmental quality may jeopardize production and adversely affect other macro-fundamentals in the economy. The determination of the optimal lending rate should reflect the overall internal rate of returns in the productive sector, with emphasis on market forces.

The results suggest that the ratio of credit to the private sector to GDP, though it reduces carbon emissions in the short run, will hurt it in the long run. The same applies to energy intensity. What this suggests is that policymakers in Nigeria must not only ensure the

enforcement of all environmental regulations designed to control carbon emissions but also promote the adoption of efficient and environmentally friendly technologies. In addition, policymakers must encourage green financing and promote the adoption of renewable energy in the energy mix. Finally, since per capita income increases carbon emissions, there is a need to introduce new low-carbon technologies to attain the same or even higher production levels at lower carbon emissions in the long run.

The current research has examined the effect of the lending rate on carbon emissions and their nonlinear relationship in Nigeria. Nevertheless, some areas require further empirical inquiry to understand the link between lending rate and carbon emissions. These include extending the research to other developing and developed countries to make comparative assessments. Moreover, future studies should explore the role of socio-political conditions on the nexus between the lending rate and carbon emissions using estimation techniques such as the Markov-Switching models and Bayesian Time-Varying Parameter Autoregression (TVP-VAR) models.

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## Appendix 1

**Table 11: Bounds test for cointegration in the linear and nonlinear specifications**

Dependent Variable: $\Delta Co_2$	F-PSS	95% Lower bound	95% Upper bound	Result
Linear ARDL	3.139	2.27	3.28	Indeterminate
Non-Linear ARDL <sup>a</sup>	8.798	2.62	3.86	Cointegration
Non-linear ARDL with the imposed short-run symmetric	4.77	2.62	3.86	Cointegration
Bound test at 5%.				