

## Is Financial Development Important for Zambia's Low Carbon Growth? An Extension of the STIRPAT Model

Martha Musa<sup>1</sup>, Ashiru Ibrahim<sup>2</sup>, & Ibrahim Enagi Saidu\*<sup>1</sup>

<sup>1</sup>Department of Economics, IBB University Lapai, Niger State

<sup>2</sup>Department of Economics, Nigerian Defence Academy, Ribadu Campus Kaduna, Kaduna State.

\*Correspondence Email: [ebraheemenagi@gmail.com](mailto:ebraheemenagi@gmail.com)

### Abstract

*Following the growing global concerns about environmental sustainability, this study aimed to assess the role of financial development in Zambia's low carbon growth using an asymmetric approach. Data collected from secondary sources for carbon dioxide emission, population, economic growth and financial development cover the period between 1980 and 2019. The results obtained from applying the nonlinear ARDL bounds technique revealed that the variables maintain a long-run relationship. Furthermore, estimates show that in the long-run, increase financial development and economic growth deter the achievement of low carbon growth while in the short-run, economic growth alone supports low carbon growth. Meanwhile, population and financial development were found to have no effect on carbon emissions in both the long-run and short-run. Accordingly, the study recommends that relevant government authorities should put policies in place, which encourages green investment and a switch over to cleaner energy sources. This would support a sustainable environment as the economy grows and becomes financially developed.*

**Keywords:** Financial development, CO<sub>2</sub> emissions, STIRPAT, Economic growth, Population, Asymmetry

**JEL Classification:** G20, O40

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### 1. Introduction

It is a widely known fact that high rates of carbon dioxide (CO<sub>2</sub>) emissions translate into air pollution, which is harmful to human health. A scientific consensus holds that carbon emissions emanating from human activities (industrial and otherwise) pose a risk to climate stability and sustainability (Yang, Wang, Chang, Wong & Li, 2022). The Intergovernmental Panel on Climate Change (IPCC) has cautioned governments about the global average temperature, which has been on the rise as a result of anthropogenic production of greenhouse gases (IPCC, 2014). This has drawn the attention of governments globally towards achieving low carbon growth in the economy with less strain on the environment (Nwani & Omoke, 2020). Consequently, it has led to the adoption of a global agreement, the "2016 Paris Agreement", which mandates member countries to keep

global temperatures under 2°C (Phiri, Malec, Kapuka, Maitah, Appiah-Kubi, Gebeltova, Bowa & Maitah, 2021). Hence, a change in technology, production methods, as well as consumption patterns through financial development is required for the achievement of this target (Jianguo, Ali, Alnor & Ullah, 2022).

Financial development has been identified in the literature as a driver of sustainable and rapid economic expansion due to improved access to credit facilities. Financial development has been hypothesised to affect the quality of the environment in two major ways. Firstly, it eases the access of households to low-cost credit, which enables them to acquire high energy-demanding infrastructure and assets such as cars or increase their demand for mobility, which in turn increases the carbon emission rate (Gok, 2019). While it may allow firms to easily access cheap capital, allowing them to buy more equipment and machines and build new plants, increasing industrial energy consumption (Acheampong, 2019). Secondly, financial development increases foreign capital inflow and research and development, which improves the environment through economic growth and development. This is achieved through the adoption of cleaner energy sources and the adoption of less energy-intensive technologies. Households also have access to capital, which will enable them to switch away from environmentally-unfriendly energy sources to cleaner sources (Acheampong 2019; Abbasi & Riaz 2016). This study, thus, attempts to investigate the course of financial development on low carbon growth in Zambia.

Zambia transitioned into being a lower-middle-income economy in 2011. This has provided it access to a larger plethora of financing options, inclusive of foreign debt capital markets. However, 57.5 percent of Zambians continue to live below the international poverty line, with rural areas accounting for 77 percent (OECD, 2019). The consequence of this for households, firms, and the economy at large is the lack of access to sufficient financial intermediation, which would ensure the attainment of a sustainable environment and low carbon growth. Apart from carbon emissions from transportation, which are on the rise due to high poverty levels that limit the acquisition of cleaner mobility infrastructure by the larger population, high demand for firewood and charcoal have significantly contributed to carbon emissions in Zambia (Ministry of Lands and Natural Resources, 2017). Deforestation in Zambia amounts to about 300,000 hectares of annual forest land loss, which is mostly due to demand for household energy and cooking fuel (Ministry of Lands and Natural Resources, 2017). At the same time, this increases the availability of harmful carbon in the atmosphere through the reduction of trees, which sequester carbon, and at the same time, adds to the quantity of carbon through biomass burning.

Furthermore, demographic issues, poor agricultural practice and unsustainable forest management have also been some of the major contributors to environmental degradation in Zambia (Ministry of Lands and Natural Resources, 2017). All these have acted as impediments to the success of several efforts by the Zambian government, including the 2007 National Policy on Environment, 2011 Environmental Management Act, 2012 National Climate Change Response

Strategy and the 2017 National Policy on Climate Change among others, which have been geared towards a sustainable environment.

Several studies have examined the impact of financial development on low carbon growth for different periods in different countries, using different methodologies and data (Abokyi, Appiah-Konadu, Abokyi & Oteng-Abayie, 2019; Ahmad, Khan, Rahman & Khan, 2018; Bayar, Diaconu & Maxim, 2020; Jiang & Ma, 2019; and Kamal, Usman, Jahanger & Balsalobre-Lorente, 2021). However, there has not been a consensus as to the actual impact of financial development on low carbon growth targets. This, as suggested by Gok (2019), could be because of the different situations under which each study has been conducted. This study is, nevertheless, different from previous studies in two ways: first, this study considers the case of Zambia in its analysis. From the extensive review of literature conducted, no study has been found, which examines the roles of financial development on low carbon growth in Zambia despite it being one of the highest African deforesters and contributors to carbon emissions; second, most studies that have conducted similar research have employed a single-variable case for measuring financial development with credit to the private sector as a ratio of GDP being the most common (Ehigiamusoe & Lean, 2019; Ganda, 2019; Jian, Fan, He, Xiong & Shen, 2019; Jiang & Ma, 2019; Khan, Weili & Khan, 2022; among others), while some others have employed Principal Component Analysis (PCA) in developing financial development index using mostly, a narrow view of what financial development entails (Eren, Taspinar & Gokmenoglu, 2019; Moghadam & Dehbashi, 2018; Shoaib, Rafique, Nadeem & Huang, 2020; among others). This creates the possibility of neglecting a dimension or some components in the measurement of financial development. This study employs the composite financial development index developed by the International Monetary Fund (IMF) following the studies of Sahay et al. (2015) and Svirydzenka (2016). This financial development index was built upon two dimensions of financial development (institutions and markets) with three components of measurement (access, depth, and efficiency) for each. This would allow a holistic view of financial development by examining its impact on Zambia's low carbon growth.

The remaining part of this study is structured as follows: Literature covers the review of existing related literature on the subject matter of this study; the description of analysis techniques are presented in Methods; Results brings the findings with explanations from the analysis done; and Conclusion concludes the study with conclusive statements and recommendations.

## **2. Literature Review**

Many studies have examined the interaction between financial development and measures of environmental quality have a similar theoretical background with this study, which include: how financial development stimulates the economy through improved access, volume, and availability of financial resources, investment promotion, and enhancement of research and development, which changes the course of energy consumption through technological improvement (Abokyi, Appiah-Konadu, Abokyi & Oteng-Abayie, 2019; Ahmad, Khan, Rahman & Khan,

2018; Ali, Zhimin, Asmi, Xue & Muhammad, 2021; Jian et al., 2019; and Omoke, Opuala-Charles & Nwani, 2020).

From available literature, two broad parts have been identified through which financial development could influence low carbon growth; on one hand, improved financial development could discourage low carbon growth by encouraging carbon emission through generating demand for energy intensive technology assets such as cars as well as investment in non-green ventures sectors such as the oil and gas and transportation sectors, which have been identified as the highest carbon emitting sectors (Bayar, Diaconu & Maxim, 2020; Jiang & Ma, 2019; Kamal, Usman, Jahanger & Balsalobre-Lorente, 2021; Shen, Su, Malik, Umar, Khan & Khan, 2021; Shoaib et al., 2020). On the other hand, improved financial development could make available the resources required for a transition to cleaner energy consumption and green investment, which will reduce the rate of carbon emission and, hence, translate into a cleaner environment and improved low carbon growth (Charfeddine & Kahia, 2019; Moghadam & Dehbashi, 2018; Shobande & Ogbeifun, 2021).

With data from 2000 to 2018, Haldar and Sethi (2022) used the Driscoll-Kraay Panel Corrected Estimators to examine the contributions of financial development, trade, innovation, and renewable energy to the environmental effects of information and communication technology (ICT). The panel included 16 emerging economies. The findings demonstrated both a long-term integration of the variables as well as a negligible effect of financial development on carbon emissions. Shobande and Ogbeifun (2021) used the Arellano-Bover/Blundell-Bond dynamic panel estimation technique in a different study to examine the significance of financial development and energy consumption for environmental sustainability in a panel of 24 Organisation for Economic Cooperation and Development (OECD) of countries between 1980 and 2021. According to the findings, economic growth enhances environmental sustainability during the study period.

In addition, Kamal et al. (2021) used the panel cointegration test, Fully Modified Ordinary Least Squares (FMOLS), Dynamic OLS (DOLS), and Autoregressive Distributed Lag (ARDL) techniques to investigate the roles of financial development, fiscal policy, and foreign direct investment in pollution reduction for a panel of 105 countries between 1990 and 2011. The findings indicate that while there is no discernible effect on the environment in the near term, financial development has a long-term tendency to exacerbate environmental damage. Using the ARDL and Granger causality estimation methodologies, Ali et al. (2021) investigated the economy of Pakistan as part of their research of the roles of financial development and fossil fuels in the relationship between environmental degradation and industrial development during the years 1971 to 2014. They find that there is a one-way causal relationship between carbon emissions and financial development and that there is no immediate or long-term influence of financial development on environmental degradation. Similar to this, Abokyi et al. (2019) looked at the instance of Ghana and investigated how the use of fossil fuels and financial development affected the relationship between industrialization and CO<sub>2</sub> emissions between 1871 and 2014 using the ARDL model, the Bayer-Hanck

combined cointegration test, and Granger causality tests. They find that financial development has no effect on carbon emissions in the long run or the short run. Additionally, a one-way causal relationship between financial growth and carbon emissions was found.

In a different study, Kirikkaleli, Gungor, and Adebayo (2021) investigated the Chilean economy using the Bayer-Hanck combined cointegration test, the ARDL model, FMOLS, DOLS, and Granger causality test to examine consumption-based CO<sub>2</sub> emissions, renewable energy usage, economic growth, and financial development between 1990 and 2017. According to the study, financial growth lowers carbon emissions over the long and short terms. Therefore, increased financial development enhances the quality of the environment. Using cointegration, the Vector Error Correction Model (VECM), and the causality test, Jian et al. (2019) investigated the impact of financial development, energy consumption, and economic growth on carbon emissions in China between 1982 and 2017. The analysis demonstrated a one-way causation from carbon emissions to financial development as well as a negligible impact of financial development on carbon emissions.

Asymmetry in the relationship between financial development and carbon emissions may have also been taken into account in some research. For instance, Omoke et al. (2020) used the ARDL and Nonlinear ARDL (NARDL) methodologies to assess the linear and nonlinear influences of financial development on CO<sub>2</sub> emissions in Nigeria from 1971 to 2014. The findings show that financial development has a beneficial influence on carbon emissions in the long run and the short run for negative financial development shocks and a negative impact for positive financial development shocks. By using the NARDL estimating technique, Karasoy (2019) investigated the causes of carbon dioxide emissions in Turkey from 1965 to 2015 in a different study. The study discovered that, in the long run, positive financial development shocks have a positive influence on carbon emissions, whereas negative financial development shocks have a negative impact. In the short term, however, positive shocks and lag positive shocks have a positive and negative impact, respectively. Meanwhile, Ahmad et al. (2018) used the NARDL for the years 1980 to 2014 to examine the asymmetric influence of financial development on carbon emissions in China. The results show that carbon emissions are encouraged by both positive and negative financial development shocks over the long term, while only positive financial development shocks are favourably correlated with carbon emissions over the short term. Thus, this offers the foundation for thinking about investigating the relationship's asymmetry for Zambia.

### **3. Methodology**

The data for this study is from secondary sources and covers the period from 1980 to 2019. Specifically, data on CO<sub>2</sub> (carbon emission/kt), POP (population) and GDP (economic growth/GDP per capita) were obtained from the World Bank (2021) World Development Indicators database, while data on FIN (financial development) was obtained from the International Monetary Fund, IMF (2019) Global Financial Development Database.

*Model Specification*

The pool of literature on drivers of carbon emission has been basically on either of two methodological trails- the Environmental Kuznets Curve (EKC) hypothesis or the IPAT approach. Ehrlich and Holdren (1971) hypothesised the drivers of environmental quality using the IPAT model as follows:

$$I = PAT \dots\dots\dots 1$$

Where: *I* stands for Impact (the environmental impact of human activities in the form of carbon emissions), *P* stands for Population, *A* is Affluence, and *T* is Technology. The IPAT framework was thereafter extended by Dietz and Rosa (1994) to STIRPAT (Stochastic Impact in Regression of Population, Affluence, and Technology) to aid the application of statistical procedures. By this, the STIRPAT model is given as follows:

$$I = aP^b A^c T^d \varepsilon \dots\dots\dots 2$$

Where: *a* is the model scale; *b, c and d* are exponents that become PAT parameters and  $\varepsilon$  is the stochastic disturbance term. Converting equation (2) into the natural logarithmic simple linear form gives the following:

$$\ln I_t = \alpha_0 + \beta \ln P_t + \gamma \ln A_t + \delta \ln T_t + \varepsilon_t \dots\dots\dots 3$$

In the literature, an extension of the STIRPAT model has been fashioned to include other economic variables as proxies for the *T* component (Dietz & Rosa, 1997; Nwani & Omoke, 2020). Following this, this study extends the STIRPAT model by including financial development. Hence, including financial development gives the following:

$$\ln CO_{2t} = \alpha_0 + \beta \ln POP_t + \gamma \ln GDP_t + \delta \ln FIN_t + \varepsilon_t \dots\dots\dots 4$$

Where: CO<sub>2</sub> is the impact on environment (I); POP is population (P); GDP is affluence (A); and FIN is technology (T).

Following Pesaran, Shin and Smith (2001), equation (4) is transformed into an ARDL form, which combines the long-run and short-run forms into a single reduced-form equation. This allows for observing the relationship among the variables at their levels as well as differenced forms simultaneously. The superiority of the ARDL technique against other forms of cointegration testing lies in its ability to handle cases of mixed integration. The ARDL technique can be applied in time series analysis if none of the series is integrated of an order greater than 1.

$$\Delta \ln CO_{2t} = \alpha_0 + \sigma_1 \sum_{i=0}^n \Delta \ln CO_{2t-i} + \sigma_2 \sum_{i=0}^n \Delta \ln POP_{t-i} + \sigma_3 \sum_{i=0}^n \Delta \ln GDP_{t-i} + \sigma_4 \sum_{i=0}^n \Delta \ln FIN_{t-i} + \theta_1 \ln CO_{2t-1} + \theta_2 \ln POP_{t-1} + \theta_3 \ln GDP_{t-1} + \theta_4 \ln FIN_{t-1} + \mu_t \dots\dots\dots 5$$

From equation (5),  $\Delta$  is the difference operator, which shows the variables in their short-run form,  $\sigma_1 - \sigma_4$  are the parameters of the variables in their short-run form,  $\theta_1 - \theta_4$  are the parameters of the coefficient in the long-run. From the Pesaran et al. (2001) specification, we derive a nonlinear ARDL specification following Shin, Yu and Greenwood-Nimmo (2014), which is an extension of the linear ARDL by

applying a partial cumulative sum decomposition of the focus explanatory variable (FIN) into its positive and negative changes as follows:

$$FIN_t^+ = \sum_{j=1}^t \Delta FIN_j^+ = \sum_{j=1}^t \max(\Delta FIN_j, 0) \dots\dots\dots 6$$

$$FIN_t^- = \sum_{j=1}^t \Delta FIN_j^- = \sum_{j=1}^t \min(\Delta FIN_j, 0) \dots\dots\dots 7$$

Applying the procedure in equations (6) and (7) gives the positive and negative partial cumulative sums of FIN, which measures positive and negative changes in FIN. Substituting FIN with  $FIN^+$  and  $FIN^-$  in equation (5) will give the NARDL model according to Shin et al. (2014) as follows:

$$\Delta LnCO2_t = \alpha_0 + \sigma_1 \sum_{i=0}^n \Delta LnCO2_{t-i} + \sigma_2 \sum_{i=0}^n \Delta LnPOP_{t-i} + \sigma_3 \sum_{i=0}^n \Delta LnGDP_{t-i} + \sigma_4 \sum_{i=0}^n \Delta LnFIN_{t-i}^+ + \sigma_5 \sum_{i=0}^n \Delta LnFIN_{t-i}^- + \theta_1 LnCO2_{t-1} + \theta_2 LnPOP_{t-1} + \theta_3 LnGDP_{t-1} + \theta_4 LnFIN_{t-1}^+ + \theta_5 LnFIN_{t-1}^- + \mu_t \dots\dots\dots 8$$

The NARDL model is desired based not just on the fact that it incorporates all the advantages of the linear ARDL, but also because it allows for capturing the impact of positive changes in a variable differently from the impact of negative changes (Ibrahim, Abdulrahman & Bafeto, 2021; Ibrahim, Matthias & Liman, 2020; Omoke, Nwachukwu, Ibrahim & Nwachukwu, 2022). The condition for applying the NARDL model is based on the stationarity levels of the series, which were tested using the Phillip and Perron test (1988) and the breakpoint unit root test by Zivot and Andrews (1992). The reason for combining the two tests is to ensure consistency in the event of a structural break or otherwise.

Furthermore, the presence of cointegration was tested among the series using the bounds test approach proposed by Pesaran et al. (2001). The model in equation (5) is applied for this purpose, and the f-statistics generated is compared with critical values provided by Pesaran et al. (2001) or Narayan (2005), depending on the observation sample size. If the f-statistic is greater than the upper bound critical value at 5 percent, there is cointegration among the series while when it falls below the lower bound value, cointegration does not exist. The existence of cointegration among the series gives the opportunity to examine the long-run and short-run estimates individually, which are extracted from equation (5):

$$LnCO2_t = \alpha_0 + \sigma_1 LnPOP_t + \sigma_2 LnGDP_t + \sigma_3 LnFIN_t + \mu_1 \dots\dots\dots 9$$

$$\Delta LnCO2_t = \alpha_0 + \sigma_1 \sum_{i=0}^n \Delta LnCO2_{t-i} + \sigma_2 \sum_{i=0}^n \Delta LnPOP_{t-i} + \sigma_3 \sum_{i=0}^n \Delta LnGDP_{t-i} + \sigma_4 \sum_{i=0}^n \Delta LnFIN_{t-i} + \phi \varepsilon_{t-1} + \mu_t \dots\dots\dots 10$$

Equations (9) and (10) are the representations of the long-run and short-run relationships, respectively. In equation (10),  $\phi \varepsilon_{t-1}$  represents the adjustment coefficient, which measures the speed of adjustment towards long-run equilibrium in the system. The value lies between 0 and, must be negatively signed, and should be statistically significant. After deriving the long-run and short-run estimates, the test for asymmetry is conducted using the Wald test for coefficient restriction, which tests the difference in the individual impact of positive and negative changes in financial development on carbon emission. The test is conducted by applying the following procedure:

$$\frac{-FIN_t^+}{CO2_{t-i}} = \frac{-FIN_t^-}{GDP_{t-i}} \dots\dots\dots 11$$

#### 4. Results

Table 1: Variables Description

Variable	Mean	Std. Deviation	Skewness	Kurtosis
CO2	3188.53	1620.29	1.94	6.28
POP	2.87	0.30	0.34	2.04
GDP	993.65	213.69	0.61	1.93
FIN	0.09	0.02	0.21	1.85

Source: Authors' Computation

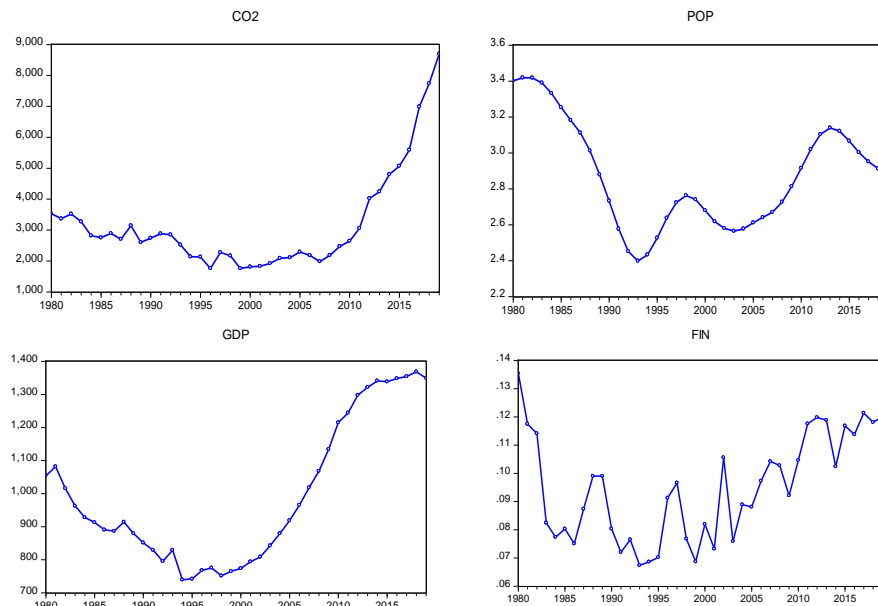


Figure 1: Linear Trends of the Variables

To test the series included in the analysis for the presence of unit root properties, the Phillip-Perron and Zivot-Andrews tests were employed and the results were obtained. Each test statistic obtained was matched with the critical value for that test and the decision was drawn accordingly. Where the test statistic obtained is greater than the critical value for that test, the conclusion is drawn that the variable is stationary at that level I(0) or first order I(1) test. Accordingly, the results are presented in Table 2.

Table 2: Stationarity Test

Variable	Phillip-Perron Test		Zivot-Andrews Test	
	I(0)	I(1)	I(0)	I(1)
CO2	0.88	-5.41*	-2.15	-7.75*
POP	-0.73	-2.14*	-6.82*	-
GDP	-0.27	-4.39*	-4.41	-6.01*
FIN	-2.62	-8.38*	-4.45*	-

Note: Phillip-Perron Critical Value = -2.94; Zivot-Andrews Critical Value = 4.44

Source: Authors' Computation



From Table 2, the Phillip-Perron test for each variable shows very small test statistics at the levels, which are smaller than the critical value of -2.94 in absolute terms and thus, necessitate further testing after taking their first difference. However, when the variables have been differenced once, the test statistics become greater than the critical value in absolute terms, thereby indicating that they are all stationary at the first difference. On the other hand, the Zivot-Andrews test has been included to account for structural breaks which could make the results of the Phillip-Perron test inefficient. Following the same rules, we conclude that population and financial development are stationary at their current levels, whereas carbon emissions and economic growth are different stationary because they become stationary only after first differencing. Hence, none of the series are integrated of an order higher than I(1). This implies that the model fulfils the criteria for an ARDL-themed analysis.

Having determined the level of integration in each series, it becomes important to examine the presence of a long-run relationship between the variables. The result is presented in Table 3.

**Table 3: Bounds Test Results**

F-Statistics	5% I(0)	5% I(1)
5.00	2.56	3.49

*Source: Authors' Computation*

Table 3 shows the F-statistic from the model, which is compared with the upper and lower 5 percent values as provided by Pesaran et al. (2001) for implementing the bounds test approach to cointegration. It is evident that there exists a long-run integration among carbon emission, financial development, economic growth and population since the f-statistic of 5.00 is greater than the 5 percent upper bound value of 3.49, this confirms that there is a long-run relationship between the variables. Following the confirmation of a long-run relationship, the long-run impact of the explanatory variables are examined on carbon emission with the results presented below.

**Table 4: NARDL Long-run Estimates**

Variable	Coefficient	Std. Error	T-statistics	P-value
POP	-0.80	0.75	-1.07	0.30
GDP	2.08	0.52	3.99	0.00
FIN <sup>+</sup>	1.23	0.52	2.35	0.03
FIN <sup>-</sup>	1.09	0.54	2.00	0.06
Constant	-5.19	3.09	-1.68	0.10

*Source: Authors' Computation*

From Table 4, population (POP), appears to have a negatively signed coefficient which would normally suggest that population growth reduces carbon emission in Zambia in the long-run. This is quite unusual, as it is usually expected that increasing population, especially in a less developed country like Zambia, will worsen the environmental quality. It is, however, not worrisome because the impact is not statistically significant judging from its corresponding probability value of 0.03 which is greater than 0.05 and thus, implies that the relationship is indeterminate. Furthermore, the positive coefficient of 2.08 for economic growth

(GDP) implies a positive long-run impact of economic growth on carbon emission in Zambia. This implies that a percentage increase in economic growth in Zambia will translate to an increase in carbon emission by 2.08 percent in the long-run. This is not unsurprising as it is expected that increased income may prompt households and firms to make consumption and investment decisions which are environmentally unfriendly. Hence, increase in economic growth in this case, will deter the achievement of low-carbon growth in Zambia. This lends support to the findings of (Ahmad et al., 2018; Kirikkaleli et al., 2021; Omoke et al., 2020; among others). Accordingly, the probability value of 0.00 implies a strong statistical significance of the impact.

Similarly, the positive change in financial development displays a coefficient of 1.23 which suggests a positive impacts of financial development on carbon emission in the long-run. This implies that a percent increase in financial development in Zambia will worsen the environmental quality by 1.23 percent. Expectedly, for a country with a high rate of poverty, increased access to financial services and credit will most likely lead households to increase their consumption of biomass fuels such as firewood and charcoal, which inject more carbon in the atmosphere and at the same time, eliminate trees which could otherwise, sequester carbon, as against the alternative of moving away to cleaner energy sources. More so, the probability value of 0.03 shows that the impact of positive changes in financial development on the environment are profound. This finding is similar to the findings of (Ahmad et al., 2018; Karasoy, 2019; among others). On the other hand, negative changes in financial development, although displaying positive coefficient of 1.09, is not statistically significant since its probability value of 0.06 exceeds the 0.05 limit.

In the short-run estimates presented in Table 5, economic growth lagged by one-year and three-year display a coefficient of -1.41 -1.91 respectively which implies that a percent increase in economic growth in the short-run, brings about a 1.41 percent to 1.91 percent decrease in carbon emission and thus, improvement in the environment. This follows the low-carbon growth postulation as it implies that when the economy of Zambia grows, its environment improves, but only in the short-run. Furthermore, the negative change in financial development displays a negative signed coefficient, which ordinarily will imply a negative impact. However, with the probability value of 0.70 which implies that the relationship is insignificant, the impact of financial development on carbon emission in the short-run cannot be determined. Also, considering the fact that the positive changes has been excluded from the model. This could mean that perhaps, financial development only affects carbon emitting activities in Zambia in the long-run and not in the short-run.

Furthermore, the adjustment term, *ECT* displays an adjustment coefficient of -0.39 which satisfies the necessary condition of negatively signed coefficient, as well as the sufficient condition of statistical significance with a probability value of 0.00. This means that random shocks to the system gets adjusted towards long-run equilibrium at a speed of 39 percent. This is considered a fast enough adjustment, considering that most less developed countries have environmental concerns lower

in their priority lists even though they make policies towards environmental sustainability.

Table 5: NARLD Short-run Estimates

Variable	Coefficient	Std. Error	T-statistics	P-value
$\Delta(\text{GDP})$	-0.11	0.43	-0.26	0.80
$\Delta\text{GDP}(-1)$	-1.41	0.51	-2.78	0.01
$\Delta\text{GDP}(-2)$	-0.42	0.48	-0.87	0.39
$\Delta\text{GDP}(-3)$	-1.91	0.42	-4.52	0.00
$\Delta\text{FIN}^-$	-0.06	0.14	-0.39	0.70
<i>ECT</i>	-0.39	0.06	-6.00	0.00

Note: *R – squared* = 0.67

Source: Authors' Computation

The dynamic NARDL multiplier plot in Figure 2 shows the adjustment path of carbon emission towards positive and negative changes in financial development. Evidently, the impact of positive changes in financial development appears to be different from the effect of the negative changes in financial development. Furthermore, the line for positive changes in financial development tend to go farther from the origin than the trend in negative changes, thereby suggesting that the effect of positive financial development changes are more pronounced than negative financial development changes. Hence, decline in financial development may not necessarily encourage low-carbon growth in Zambia, but increase in financial development will certainly retard the achievement of low carbon growth.

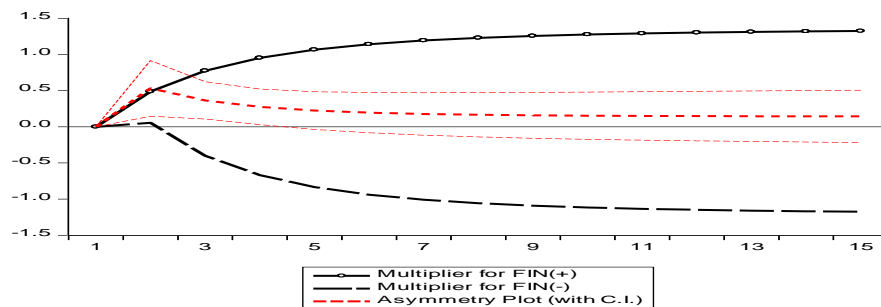


Figure 2: Dynamic NARDL Multiplier

In Table 6, the long-run asymmetric test confirms the absence of asymmetry in the impact of financial development on carbon emission, this was concluded based on the probability value, 0.53 for the Wald test f-statistic, which is greater than 0.05 and thus, implies the acceptance of the hypothesis that there is no asymmetry.

Table 6: Residual Diagnostic Tests

Test	Statistic	P-value
Long-run Asymmetry (F-statistic)	0.403	0.53
Serial Correlation (F-statistic)	1.37	0.27
Heteroskedasticity (F-statistic)	1.02	0.45
Normality (Jarque-Bera)	1.04	0.59
Ramsey RESET (F-statistic)	0.94	0.34

Source: Authors' Computation

Furthermore, the results of the model diagnostic tests including the serial correlation, heteroskedasticity, normality and functional specification, all suggest that the model is free from any issues and does not violate the classical assumptions. Additionally, the Cumulative Sum (CUSUM) and Cumulative Sum of Squares and (CUSUM of Squares) plots in Figure 3 confirms the stability of the model in the long-run, thus buttressing the residual diagnostic results.

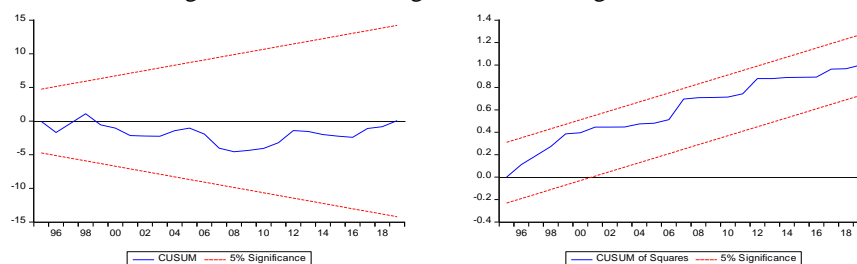


Figure 3: CUSUM and CUSUM of Squares Test for Stability

## 5. Conclusion

Zambia is a country with a high case of deforestation and forest cover loss due to incessant logging, dependence of households on biomass fuels as a source of energy for cooking, bad agricultural practices, among others ((Ministry of Lands and Natural Resources, 2017). These have in time, worsened the environmental quality as the amount of carbon in the atmosphere increase due to burning of fossil fuels and biomass, as well as decline in trees that would otherwise, sequester carbon from the atmosphere. However, in recent times, the government have made efforts towards sustainable environment and a low carbon pattern of growth. It is based on this, that this study examined the role of financial development in low-carbon growth in Zambia.

Applying the NARDL technique, the bounds test approach to cointegration reveals the presence of long-run integration between carbon emissions, financial development, economic growth and population growth. Furthermore, economic growth in the long-run and increase in financial development were found to discourage low-carbon. Although, population and financial development in the long run do not exert any impact, economic growth was found to encourage low carbon emission in Zambia.

Going by these, it is recommended that the Zambian authorities should ensure that policies which encourage green investments are encouraged in the country. This would make for the easy switch to low-carbon emitting appliances and energy sources at the household and firm level.

## References

- Abbasi, F. & Raiz, K. (2016). CO2 emissions and financial development in an emerging economy: An augmented VAR approach. *Energy Policy*, 90, 102–114. <https://doi.org/10.1016/j.enpol.2015.12.017>
- 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. <https://doi.org/10.1016/j.egyr.2019.09.002>
- Acheampong, A. O. (2019). Modelling for insight: Does financial development improve environmental quality? *Energy Economics*, 83, 156-179. <https://doi.org/10.1016/j.eneco.2019.06.025>.
- Ahmad, M., Khan, Z., Rahman, Z. U. & Khan, S. (2018). Does financial development asymmetrically affect CO2 emissions in China? An application of the nonlinear autoregressive distributed lag (NARDL) model. *Carbon Management*, 9(6), 631-644. <https://doi.org/10.1080/17583004.2018.1529998>
- Ali, M. U., Zhimin, G., Asmi, F., Xue, Z. & Muhammad, R. (2021). The nexus between environmental degradation and industrial development in Pakistan and roles of financial development and fossil fuel. *Environmental Progress and Sustainable Energy*, 40(4), e13621. <https://doi.org/10.1002/ep.13621>
- Bayar, Y., Diaconu (Maxim), L. & Maxim, M. (2020). Financial development and CO 2 emissions in post-transition European Union countries. *Sustainability*, MDPI, 12(7), 1-15. <https://doi.org/10.3390/su12072640>
- Charfeddine, L. & Kahia, M. (2019). Impact of renewable energy consumption and financial development on CO2 emissions and economic growth in the MENA region: A panel vector autoregressive (PVAR) analysis. *Renewable Energy, Elsevier*, 139(C), 198-213. <http://dx.doi.org/10.1016/j.renene.2019.01.010>
- Dietz, T. & Rosa, E. A. (1994). Rethinking the environmental impacts of population, affluence and technology. *Human Ecology Review*, 1, 277-300. Available online: <https://www.humanecologyreview.org/pastissues/her12/12dietzosa.pdf>
- Ehigiamusoe, K. U. & Lean, H. H. (2019). Effects of energy consumption, economic growth, and financial development on carbon emissions: Evidence from heterogeneous income groups. *Environmental Science and Pollution Research*, 26, 22611–22624. <https://doi.org/10.1007/s11356-019-05309-5>
- Ehrlich, P. R. & Holdren, J. P. (1971). Impact of population. *Science*, 171(3977), 1212-1217. <https://doi.org/10.1126/science.171.3977.1212>
- Eren, B. M., Taspinar, N. & Gokmenoglu, K. K. (2019). The impact of financial development and economic growth on renewable energy consumption: Empirical analysis of India. *The Science of the Total Environment*, 663, 189–197. <https://doi.org/10.1016/j.scitotenv.2019.01.323>
- Ganda, F. (2019). The environmental impacts of financial development in OECD countries: A panel GMM approach. *Environmental Science and Pollution Research*, 26, 6758–6772. <https://doi.org/10.1007/s11356-019-04143-z>
- Gök, A. (2020). The role of financial development on carbon emissions: A meta-regression analysis. *Environmental Science and Pollution Research*, 27, 11618–11636. <https://doi.org/10.1007/s11356-020-07641-7>
- Haldar, A. & Sethi, N. (2022). Environmental effects of information and communication technology: Exploring the roles of renewable energy, innovation, trade and financial development. *Renewable and Sustainable Energy Reviews*, 153, 111754, <https://doi.org/10.1016/j.rser.2021.111754>

- Ibrahim, A., Abdulrahman, L. & Bafeto, A. (2021). Bank credit and manufacturing sector output in Nigeria: A nonlinear approach. *Lapai Journal of Economics*, 5(1), 32-46.
- Ibrahim, A., Matthias, C. I. & Liman, K. (2020). Balance of payments response to crude oil price asymmetry in Nigeria: An NARDL approach. *Lapai Journal of Economics*, 4(2), 56-70.
- IMF (2019). Financial Development Index Database 2019. Available online: <https://data.imf.org/?sk=F8032E80-B36C-43B1-AC26-493C5B1CD33B>
- IPCC (2014). Climate change 2014: synthesis report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on the Climate Change. Retrieved from <https://www.ipcc.ch/report/ar5/syr/>
- Jian, J., Fan, X., He, P., Xiong, H. & Shen, H. (2019). The effects of energy consumption, economic growth and financial development on CO2 emissions in China: A VECM approach. *Sustainability*, 11, 4850. <https://doi.org/10.3390/su11184850>
- Jiang, C. & Ma, X. (2019). The impact of financial development on carbon emissions: A global perspective. *Sustainability*, 11(19), 5241. <https://doi.org/10.3390/su11195241>
- Jianguo, D., Ali, K., Alnori, F. & Ullah, S. (2022). The nexus of financial development, technological innovation, institutional quality, and environmental quality: Evidence from OECD economies. *Environmental Science and Pollution Research*. <https://doi.org/10.1007/s11356-022-19763-1>
- Kamal, M., Usman, M., Jahanger, A. & Balsalobre-Lorente, D. (2021). Revisiting the role of fiscal policy, financial development, and foreign direct investment in reducing environmental pollution during globalization mode: Evidence from linear and nonlinear panel data approaches. *Energies*, 14, 6968. <https://doi.org/10.3390/en14216968>
- Karasoy, A. (2019). Drivers of carbon emissions in Turkey: considering asymmetric impacts. *Environmental Science and Pollution Research*, 26, 9219–9231. <https://doi.org/10.1007/s11356-019-04354-4>
- Khan, H., Weili, L. & Khan, I. (2022). Institutional quality, financial development and the influence of environmental factors on carbon emissions: Evidence from a global perspective. *Environmental Science and Pollution Research*, 29, 13356–13368. <https://doi.org/10.1007/s11356-021-16626-z>
- Kirikkaleli, D., Güngör, H. & Adebayo, T. S. (2021). Consumption-based carbon emissions, renewable energy consumption, financial development and economic growth in Chile. *Business Strategy and the Environment*, 31(3), 1123-1137. <https://doi.org/10.1002/bse.2945>
- Ministry of Lands and Natural Resources (2017). National Investment Plan to Reduce Deforestation and Forest Degradation (2018-2022). Available online: [https://climateinvestmentfunds.org/sites/default/files/meeting-documents/zambia\\_final\\_investment\\_plan\\_fip.pdf](https://climateinvestmentfunds.org/sites/default/files/meeting-documents/zambia_final_investment_plan_fip.pdf)
- Moghadam, H. E. & Dehbashi, V. (2018). The impact of financial development and trade on environmental quality in Iran. *Empirical Economics*, Springer, 54(3), 1777-1799. <https://link.springer.com/article/10.1007%2Fs00181-017-1266-x>

- Narayan, P. K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics*, 37, 1979-1990. <https://doi.org/10.1080/00036840500278103>
- Nwani, C. & Omoke, P. C. (2020). Does bank credit to the private sector promote low-carbon development in Brazil? An extended STIRPAT analysis using dynamic ARDL simulations. *Environmental Science and Pollution Research International*, 27(25), 31408–31426. <https://doi.org/10.1007/s11356-020-09415-7>
- OECD (2019). Transition Finance 2019 – Zambia. Available online: <https://www.oecd.org/dac/financing-sustainable-development/development-finance-topics/Zambia-Transition-Finance-country-pilot.pdf>
- Omoke, P. C., Nwachukwu, T., Ibrahim, A. & Nwachukwu, O. (2022). Asymmetric impact of financial development, trade openness, and environmental degradation on economic growth in Venezuela. *Environmental Science and Pollution Research International*, 29(18), 27411–27420. <https://doi.org/10.1007/s11356-021-18421-2>
- Omoke, P. C., Opuala-Charles, S. & Nwani, C. (2020). Symmetric and asymmetric effects of financial development on carbon dioxide emissions in Nigeria: Evidence from linear and nonlinear autoregressive distributed lag analyses. *Energy Exploration & Exploitation*, 38(5), 2059–2078. <https://doi.org/10.1177%2F0144598720939377>
- 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. Available online: <https://www.jstor.org/stable/2678547>
- Phillips, P. C. B. & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75(2), 335–346. <http://dx.doi.org/10.1093/biomet/75.2.335>
- Phiri, J., Malec, K., Kapuka, A., Maitah, M., Appiah-Kubi, S. N. K., Gebeltová, Z., Bowa, M. & Maitah, K. (2021). Impact of agriculture and energy on CO2 emissions in Zambia. *Energies*, 14, 8339. <https://doi.org/10.3390/en14248339>
- Sahay, R., Čihák, M., N'Diaye, P., Barajas, A., Mitra, S., Kyobe, A., Mooi, Y. N. & Yousefi, S. R. (2015). Financial inclusion: Can it meet multiple macroeconomic goals? IMF Working Paper SDN/15/17. Available online: <https://www.imf.org/external/pubs/ft/sdn/2015/sdn1517.pdf>
- Shen, Y., Su, Z.-W., Yousaf, M., Umar, M., Khan, Z. & Khan, M. (2021). Does green investment, financial development and natural resources rent limit carbon emissions? A provincial panel analysis of China. *Science of the Total Environment*, 755(2), 142538. <https://doi.org/10.1016/j.scitotenv.2020.142538>
- Shin, Y., Yu, B. & Greenwood-Nimmo, M. (2014). Modeling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Horrace, W. C. & Sickles, R. C., Eds., *Festschrift in Honor of Peter Schmidt: Econometric Methods and Applications*, Springer Science & Business Media, New York, 281-314. [https://doi.org/10.1007/978-1-4899-8008-3\\_9](https://doi.org/10.1007/978-1-4899-8008-3_9)
- Shoaib, H. M., Rafique, M. Z., Nadeem, A. M. & Huang, S. (2020). Impact of financial development on CO2 emissions: A comparative analysis of developing countries (D8) and developed countries (G8). *Environmental*

- Science and Pollution Research*, 27, 12461–12475.  
<https://doi.org/10.1007/s11356-019-06680-z>
- Shobande, O. A. & Ogbeifun. L. (2021): The criticality of financial development and energy consumption for environmental sustainability in OECD countries: Evidence from dynamic panel analysis. *International Journal of Sustainable Development & World Ecology*, June, 153-163.  
<https://doi.org/10.1080/13504509.2021.1934179>
- Svirydzenka, K. (2016). Introducing a new broad-based index of financial development. IMF Working Paper. 2016. Available online:  
<https://www.imf.org/external/pubs/ft/wp/2016/wp1605.pdf>
- World Bank (2021). 2020 World Development Indicators Report. Available online:  
<https://databank.worldbank.org/source/world-development-indicators>  
(accessed on 15 April, 2022).
- Yang, Z., Wang, M-C., Chang, T., Wong, W-K. & Li, F. (2022). Which factors determine CO2 emissions in China? Trade openness, financial development, coal consumption, economic growth or urbanization: Quantile Granger causality test. *Energies*, 15, 2450. <https://doi.org/10.3390/en15072450>
- Zivot, E. & Andrews, D. W. K. (1992). Further evidence on the Great Crash, the Oil-price shock, and the unit-root hypothesis. *Journal of Business and Economic Statistics*, 10(3), 251-270. <http://dx.doi.org/10.2307/1391541>