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The Effect of Carbon Emissions on Financial Development, Capital Formation and Economic Growth in Nigeria

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Abstract

This study examines the impact of carbon emissions (CO2) on financial development, capital formation, and economic growth in Nigeria from 1991 to 2021. Using the ARDL model and the Toda-Yamamoto causality test. The findings show a positive and significant relationship between economic growth and carbon emissions in the short run, but a negative and significant relationship in the long run. Domestic credit to the private sector has a positive and significant impact on economic growth in both the short and long run. Gross fixed capital formation has a negative and significant impact on economic growth in the short run, but a positive and significant impact in the long run. Trade openness also has a positive and significant impact on economic growth in both the short and long run. The study also reveals a one-way relationship between economic growth and CO2 emissions. These findings suggest governments should prioritize sustainable development and reduction of carbon emissions by investing in renewable energy, improving energy efficiency, and promoting sustainable transportation. Additionally, governments should invest in human capital and infrastructure, including spending on education, healthcare, and transportation.

Keywords: CO_2, Financial Development, Capital Formation, Economic Growth, ARDL
JEL Classification Code: Q5, G2, O4, E22

1. Introduction

Global warming and climate change are increasingly impacting the lives of humans, animals, and plants (Zhang and Liu, 2019). The primary cause of global warming is greenhouse gas emissions, particularly carbon dioxide (CO_2) (Liu et al., 2016; Lin et al., 2017). In 2012, global carbon emissions rose by 1.4% due to the world's economic growth, reaching a total of 34.5 billion tonnes (Behket et al., 2017). As of 2021, global carbon dioxide emissions have reached a record high of 147.2 billion metric tons ($GtCO_2$) (Fatima et al., 2021a; Rafique et al., 2021; Shahzad et al., 2021).
However, Economists and policymakers worldwide have prioritized economic growth as a key concern. However, this growth often leads to negative environmental consequences, including the over-exploitation of natural resources, destruction of wildlife habitats, and climate change. The burning of fossil fuels, such as coal, petroleum, and natural gas, which have become increasingly popular during industrialization, is a primary cause of global warming. The main sources of carbon dioxide (CO_2) emissions are the production of fossil fuels, industrial activity, and deforestation, all of which contribute to the increase of greenhouse gases in the atmosphere. (Jamiu & Husam, 2020; Okere et. al., 2021).
Capital formation is the process of accumulating and investing capital goods, such as machinery, equipment, infrastructure, and inventory. It is essential for economic growth, as it allows businesses to produce more goods and services, and for workers to become more productive. This

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is essential for economic growth, as it allows businesses to produce more goods and services. However, capital formation can also lead to increased CO_2 emissions, as many types of physical capital require energy to operate and maintain (Onwiodiokit, & Otolorin, 2021; Nadabo, 2023).
By and large, Nigeria, along with the rest of the world, is facing the harmful effects of high carbon emissions. Carbon dioxide (CO_2) is a significant greenhouse gas that contributes to climate change. This, in turn, can result in detrimental environmental consequences like increased temperatures, rising sea levels, extreme weather events, and disruptions to ecosystems. These environmental problems can also have lasting economic impacts (Yao & Ameyaw, 2018).
Figure 1 illustrates the trends in carbon emissions, financial development proxied by credit to the private sector, capital formation, and economic growth in Nigeria from 1991 to 2021 at 5-year intervals. Carbon emissions have consistently increased during this period, rising from 37.6 million metric tons in 1991 to 147.2 million metric tons in 2021. This rise can be attributed to various factors, including population growth, economic development, and urbanization. Credit to the private sector has also shown a steady increase, growing from 20.5% of GDP in 1991 to 62.0% of GDP in 2021. This suggests that Nigeria's financial system is becoming more advanced and businesses are gaining better access to credit.
Furthermore, capital formation has experienced growth, increasing from 14.2% of GDP in 1991 to 35.0% of GDP in 2021. This indicates that Nigeria is investing more in infrastructure and other productive assets. Economic growth has also seen a positive trajectory, rising from 3.4% in 1991 to 18.0% in 2021. This can be attributed to factors such as the increase in credit to the private sector, the rise in capital formation, and other reforms that have enhanced the business environment in Nigeria.

Fig 1.

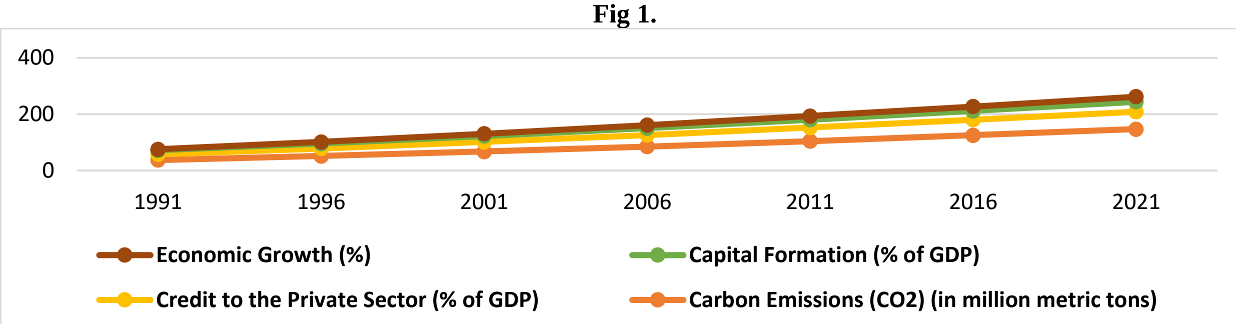


Figure 1 illustrates the relationship between carbon emissions (CO_2), credit to the private sector, capital formation, and economic growth in Nigeria from 1991 to 2021.
Source: Author’s Compilation (2023).

Additionally, there are interrelationships between the variables in the figure. For instance, the increase in credit to the private sector is likely to have contributed to the growth in capital formation and economic growth. Similarly, the increase in capital formation is likely to have influenced the rise in economic growth. However, it is important to acknowledge that these relationships are intricate, and other factors can also impact the variables. For instance, the global economic crisis of 2008-2009 resulted in a decline in economic growth in Nigeria, despite the continued growth in credit to the private sector and capital formation.
The complex relationship between financial development, capital formation, and environmental degradation, particularly in the context of carbon emissions, has been the subject of numerous investigations aimed at identifying effective mitigation strategies (Tamazian & Rao, 2010; Ozturk & Acaravci, 2013; Shahbaz et al., 2016; Bekhet et al., 2017; Salahuddin et al., 2018; Haseeb et. al., 2018; Halliru et. al., 2020; Faisal et. al., 2020; Abid et. al., 2021). This study is motivated by the persistent ambiguity surrounding the intricate interplay between these factors. However, based

on our knowledge and the literature reviewed, the majority of the studies that were reviewed utilized theoretically based models and various analysis methods. Surprisingly, none of the studies reviewed in this research utilized the ARDL bounds testing or the Toda-Yamamoto causality technique to investigate the relationship between carbon emissions and financial development, capital formation, and economic growth in Nigeria. This study aims to bridge this gap by employing the aforementioned econometric methods to examine the effects of carbon emissions on financial development, capital formation, and economic growth in Nigeria from 1991 to 2021. This study aims to delve into the intricate relationship between carbon dioxide (CO2) emissions, financial development, capital formation, and economic growth in Nigeria. The specific objectives of this investigation are to:

i. Explore the nexus between CO2 emissions, financial development, capital formation, and economic growth in Nigeria.

ii. Ascertain the causal linkages between CO2 emissions, financial development, capital formation, and economic growth in Nigeria.

2. Literature Review

2.1 Conceptual Literature

Concept of Carbon Emission

Carbon dioxide (CO_2) is a significant greenhouse gas that retains heat in the Earth's atmosphere. It is the primary greenhouse gas released through human activities. Carbon emissions arise from the combustion of fossil fuels like coal, oil, and natural gas, as well as from deforestation and industrial processes (World Bank, 2023). Carbon dioxide represented as (CO_2) is released into the earth mostly by the burning of carbon-containing fuel and the decay of wood and other matters (Muftau & Iyoboyi, 2018). Carbon emissions refer to the discharge of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere due to human activities. CO_2 is the main greenhouse gas emitted by human activities and is accountable for approximately 65% of the observed warming since the pre-industrial period (Ramanathan, 2018).

Concept of Economic Growth

Different researchers and schools have varying definitions of economic growth. Sari (2017) argues that it occurs when the gross domestic product or national income increases. Similarly, Essien (2001) defines it as a percentage of real income over a given period, usually one year. Babangida (2013) believes it refers to the process of increasing income or output over time. According to Desmond et al. (2015), GDP is the market value of all officially recognized goods and final services produced in a country at a given time. Hagen (1970) defines it as the increase in per capita income resulting from the increase in per capita production. Economic growth has always been a top priority for countries, whether they are developed or developing. It refers to the long-term increase in an economy's ability to produce a wide range of goods for its citizens. This growth is driven by advancements in technology, institutions, financial development, and the necessary ideological changes (Kuznets, 1955; Lewis, 1978).

Concept of Financial Development

According to McKinnon and Shaw (1973), financial development refers to the structural transformation of the financial system. This transformation includes the expansion of financial institutions and markets, as well as the greater accessibility of financial instruments and services. The financial sector includes institutions, instruments, markets, and regulations that enable credit transactions. Its development involves reducing costs in the financial system, such as acquiring information, enforcing contracts, and making transactions. This has led to the emergence of financial contracts, markets, and intermediaries. Different countries and periods have seen variations in these aspects due to factors like information, enforcement, transaction costs, and legal systems (World Bank, 2023).

Concept of Capital Formation

According to Nurkse, (1953), capital formation refers to the increase in the stock of capital goods, which includes human capital. Bakare (2011) defines capital formation as the current savings that are not spent and are intended to enhance future productivity and output. The World Bank, (2023) describes capital formation as the process of augmenting the stock of capital goods in an economy. These capital goods are physical assets used in the production of other goods and services, such as machinery, equipment, and infrastructure. Capital formation is crucial for economic growth, as it enables businesses to expand their production capacity and generate a greater quantity of goods and services.

2.2 Theoretical Literature Review

The Environmental Kuznets Curve (EKC) theory

Developed by Simon Kuznets in 1955, the Environmental Kuznets Curve (EKC) theory explores the intricate connection between economic development and environmental degradation. It posits a U-shaped relationship between these two factors, suggesting that environmental degradation initially intensifies during the early stages of economic growth, but gradually declines as countries achieve higher levels of development. While numerous empirical studies support the EKC theory, several others have revealed a more complex relationship than the theory initially proposed (Grunewald et al., 2009; Chowdhury et al., 2012; Kaika et al., 2013; Choumert et al., 2013; Liu et al., 2018; Ahmad et al., 2020; Minlah et al., 2020; Ahmad et al., 2021; Isik et al., 2021; Sadiq et al., 2022). These findings highlight the need for a more nuanced understanding of the interplay between economic growth and environmental sustainability.

Solow Neo-Classical Growth Model

In 1956, Robert Solow's neoclassical growth model extended the Harrod-Domar framework by incorporating labour as an additional input and technology as an exogenous variable. Unlike the Harrod-Domar model, which posited fixed coefficients and constant returns to scale, Solow's model demonstrated diminishing returns to individual factors of labour and capital, but constant returns when considered collectively. Technological advancement was considered the primary driver of long-term economic growth and was assumed to be externally determined, independent of other factors. This theory postulates that economic growth is fueled by the interplay of labour, capital, and technological progress. While an economy's resources in terms of labour and capital are finite, technology's contribution to growth is perceived as boundless.

Empirical Literature Review

An investigation by Ameyaw and Yao (2018) utilized the panel methodology to explore the connection between gross domestic product (GDP) and CO2 emissions in five West African countries between 2007 and 2014. The study's findings revealed a significant impact on carbon dioxide emissions. Bekar (2018) employed the Toda-Yamamoto and VAR causality analysis to delve into the relationship between CO2 emissions and economic growth in Turkey from 1977 to 2014. The results indicated a positive correlation between increasing CO2 emissions and GDP growth.

In a study of eight West African Economic and Monetary Union (WEMU) countries from 1970 to 2010, Ouoba (2017) employed the autoregressive distributed lag (ARDL) method to examine the relationship between carbon dioxide emissions and economic growth. The study's findings revealed no long-term correlation between carbon dioxide emissions and job creation in the eight WEMU countries. Only Benin, Mali, and Togo exhibited evidence supporting the quadratic carbon Kuznets curve. Similarly, Alege et al. (2016) utilized Johansen's maximum covariance test to investigate the correlation between emissions, energy consumption, and economic growth in Nigeria from 1970 to 2013. The authors discovered a positive relationship between carbon dioxide emissions and GDP per capita.

Mir and Storm (2016) also employed the carbon Kuznets curve theory to analyze data from 40 countries (and 35 economies) between 1995 and 2007. The study accurately estimated CO_2 emissions per capita by considering all carbon emissions occurring in the world. economy and international networks. While there is evidence of decoupling between growth and production based on CO_2 emissions, emissions based on consumption increase consistently with GDP per capita. Abubakar and Kassim (2016) emphasize the importance of diagnostic tests in ensuring the validity of models and producing policy-relevant findings. Their work addresses a critical gap in the literature by examining the nexus between CO2 emissions and economic growth in the Nigerian context. They employ the novel ARDL approach to conduct the necessary statistical tests.

Azam et al. (2015) found that carbon dioxide emissions harm economic growth in economies with higher CO2 emissions, while Alshehry (2015) found that per capita energy consumption and per capita GDP contributed to increased carbon dioxide emissions in Saudi Arabia. Kasperowicz (2015) showed a negative relationship between GDP and carbon dioxide emissions in 18 EU member states, while Mesagan (2015) found that economic growth has a positive impact on Nigeria's carbon emissions. In Nigeria, Ejuvbekpokp (2014) analyzed the relationship between carbon emissions and economic growth from 1980 to 2010 using OLS regression. The results indicated that carbon emissions have a detrimental impact on Nigeria's economic growth.

Öztürk and Uddin (2012) employed a cointegration model to examine the long-term Granger causality between these variables in India from 1971 to 2007. Their findings suggest a causal link between economic growth and energy consumption in India. Similarly, Kumar (2011) utilized the VAR framework to investigate the correlation between energy consumption, CO2 emissions, and economic growth in India from 1971 to 2007. The results indicate that carbon dioxide emissions negatively impact GDP. Inspired by these studies, this research aims to delve into the long-term causal relationship between electricity consumption, carbon emissions, and economic growth in Nigeria from 1970 to 2008.

The study by Boopen and Vinesh (2011) examined the relationship between Mauritius's GDP and carbon dioxide emissions from 1975 to 2009. Their findings indicate a strong correlation between the path of GDP and carbon dioxide emissions. Moreover, the study reveals that the influence of emissions on income has increased over time. Alege (2005) did not conduct any diagnostic tests as part of their investigation. This study differs from previous research on Nigerian economic growth and CO_2 emissions in several ways. Firstly, based on the available literature, no previous research has examined the link between CO_2 and growth in Nigeria using the recent ARDL estimation method.

An analysis of the relationship between economic development and CO2 emissions in Jordan was conducted by Mugableh (2015), who examined the equilibrium and dynamic causality relationships among economic development, CO_2 emissions, energy consumption, financial development, foreign direct investment inflows, and gross fixed capital formation. The study, which covered the period from 1976 to 2010, found evidence supporting the Environmental Kuznets Curve hypothesis, indicating that as a country develops, CO_2 emissions initially increase but eventually decline. Additionally, the study revealed that foreign direct investment and gross fixed capital formation have a positive impact on economic growth in the long term, potentially leading to an increase in CO_2 emissions in the short term. Furthermore, a bidirectional causality relationship was observed between economic development and energy consumption in Jordan.

Shahbaz et al. (2016) investigated the asymmetric relationship between energy consumption and economic growth in India, employing a production function that incorporated financial development, capital, and labour. Their analysis, which spanned the period from 1960Q1 to 2015Q4, indicated that negative shocks to energy consumption and financial development can hinder economic growth in India. Conversely, capital formation was found to have a positive impact on economic growth. Notably, the labour force did not exert a significant influence on economic growth during the study period.

A study by Bekhet et al. (2017) investigated the dynamic interconnections between financial development, economic growth, energy consumption, CO_2 emissions, and gross fixed capital formation in Malaysia. Utilizing time series data spanning from 1970 to 2013, the authors employed the ARDL model to unravel the intricate relationships among these variables. Their findings revealed a positive correlation between financial development and economic growth, on the one hand, and energy consumption and CO_2 emissions, on the other. Gross fixed capital formation, while exhibiting a positive association with energy consumption, exerted a negative influence on CO_2 emissions. Furthermore, the study uncovered a bidirectional causal relationship between economic growth and both energy consumption and CO_2 emissions in the short run.

A study by Mi et al. (2017) employed structural decomposition analysis and environmental input-output analysis to determine the key factors influencing China's carbon emission trends from 2005 to 2012. Their findings revealed that economic growth and energy intensity were the primary drivers of carbon emissions during this period, while population size, industrial structure, and energy structure played a lesser role. Zaidi et al. (2019) use advanced econometric techniques to analyze panel data and investigate the effects of export product quality and renewable energy on sustainable production. Their results indicate that higher export product quality positively affects sustainable production, while renewable energy has a negative impact. These findings highlight the importance of promoting export product quality and renewable energy for improving sustainable production.

An investigation conducted by Omri et al. (2015) explored the intricate relationship between financial development, carbon dioxide (CO_2) emissions, trade, and economic growth. The researchers employed simultaneous-equation panel data models for a panel of 12 Middle East and North Africa (MENA) countries spanning from 1990 to 2011. The study unveiled a bidirectional causal interaction between CO_2 emissions and economic growth. This suggests that economic growth fosters higher CO_2 emissions, and conversely, CO_2 emissions can influence economic growth. Furthermore, the study identified a bidirectional causal relationship between trade openness and economic growth, implying that trade openness promotes economic growth, and economic growth can in turn increase trade openness.

Aye et al. (2017) delved into the impact of economic growth on CO_2 emissions in Turkey from 1974 to 2014. They employed various econometric techniques to analyze the intricate relationship between per capita GDP, per capita CO_2 emissions, financial development, renewable energy consumption, hydropower consumption, alternative energy consumption, and urbanization. The results revealed a U-shaped relationship between economic growth and CO_2 emissions, indicating that economic growth initially leads to a decline in CO_2 emissions in the low-growth regime, followed by an increase in CO2 emissions as economic growth accelerates into the high-growth regime.

Charfeddine et al. (2019) employed a panel vector autoregressive (PVAR) model to examine the impact of renewable energy and financial development on CO2 emissions and economic growth in the MENA region. Their findings suggest that renewable energy consumption negatively influences CO2 emissions, while financial development positively impacts economic growth but negatively affects CO2 emissions. Similarly, Al-Mulali et al. (2015) investigated the relationship between renewable electricity production, CO2 emissions, economic growth, electricity consumption, and financial development in 23 European countries and GCC countries. Their study revealed that all forms of renewable electricity production significantly reduce CO2 emissions, with solar and wind power having the most substantial impact.

Halliru et al. (2020) examined the relationship between economic growth and carbon dioxide (CO2) emissions in the Economic Community of West African States (ECOWAS) from 1970 to 2017 using panel quantile regression. Their findings suggest a non-linear relationship between economic growth and CO2 emissions, with CO2 emissions increasing in all ECOWAS countries as economic growth accelerates. This contradicts the traditional Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted U-shaped relationship between economic growth and environmental degradation. The study also found that trade openness harms environmental performance in low-emission countries, while the impact of financial development on CO2 emissions varies across quantiles. Human capital, on the other hand, consistently exhibits a positive effect on CO2 emissions. To mitigate the environmental consequences of economic growth, the authors recommend implementing policies that promote sustainable development, such as investing in green infrastructure, enhancing energy efficiency, establishing carbon pricing mechanisms, strengthening environmental regulations, and fostering environmental awareness and education.

Zhang et al. (2021) investigated the long-term and causal effects of economic growth, financial development, urbanization, and gross capital formation on Malaysia's CO2 emissions using the STIRPAT framework. Researchers in Malaysia discovered that CO2 emissions are positively influenced by economic growth, financial development, and gross capital formation. Urbanization, on the other hand, was found to have a negative impact. Adebayo et al. (2021) used the ARDL method to analyze the long- and short-term relationship between CO2 emissions and the regressors in Nigeria from 1981 to 2019. The study found that CO2 emissions and economic growth are positively correlated in the long run in Nigeria. This suggests that as Nigeria's economy grows, its CO2 emissions are likely to increase as well.

In a recent study, Farooq et al. (2023) delved into the factors that significantly influence CO2 emissions in the GCC region. Their analysis encompassed data from six GCC economies – Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates – spanning the period from 2000 to 2019. Utilizing fully modified ordinary least square and generalized least square methods, the researchers conducted a regression analysis that revealed a positive and statistically significant correlation between economic growth, foreign investment, urbanization, and CO2 emissions in the GCC region. Conversely, governance quality and renewable energy consumption exhibited a negative and statistically significant impact on CO2 emissions.

3. Methodology

3.1 Theoretical Framework

This study builds upon Solow's neoclassical theory of economic growth, which has also been examined by Akinkunmi (2017) and Bekar (2018). Consistent with Solow's theory, this study emphasizes the significance of labour, capital, and technology in driving economic growth. Solow argues that technological progress, the primary catalyst for long-term growth, is determined autonomously from other factors. This relationship can be represented as:

$$Y = f(T) \qquad (1)$$

Where Y is economic growth and T is technology
Equation (1) can be transformed as; follows:

$$Y_t = \beta_o + \beta 1\ T_t + \mu_t \qquad (2)$$

Equation (2) demonstrates that economic growth is influenced by technological progress, with a positive correlation between the two variables. To account for additional factors affecting economic growth, the equation was adjusted to incorporate carbon emissions (CO_2) as a measure of technological progress. Researchers have argued that emissions have a long-term effect on growth (Alshehry, 2015; Kasperowicz, 2015). The revised relationship can be expressed as follows:

$$GDP_t = \beta_o + \beta_1 CO2_t + \mu_t \qquad (3)$$

Several additional factors have been identified in the literature as having a significant impact on economic growth. These include trade openness, financial development, foreign direct investment, and investment. These variables are theoretically linked to the dependent variable and have been shown to exert a positive influence on economic growth in various empirical studies. Therefore, the general theoretical framework for this study is as follows:

$$GDP_t = f\ (CO2_t, DCPS_t, TOPN_t, FDI_t, GFCF_t) \qquad (4)$$

Where: GDP represents economic growth, CO_2 signifies carbon emissions, DCPS refers to domestic credit to the private sector, TOPN stands for trade openness, FDI represents foreign direct investment, and GFCF represents gross fixed capital formation.

3.2 Model Specification

The general economic growth model including variable of interest (carbon emission) and other important determinants of economic growth such as DCPS, TOPN, FDI and GFCF is specified as follows;

$$GDP_t = \partial_o + \partial_1 CO2_t + \partial_2 DCPS_t + \partial_3 TOPN_t + \partial_4 FDI_t + \partial_5 GFCF_t + \varepsilon \qquad (5)$$

Where: GDP represents economic growth, CO2 signifies carbon emissions, DCPS refers to domestic credit to the private sector, TOPN stands for trade openness, FDI represents foreign direct investment, and GFCF represents gross fixed capital formation, ∂_1, ∂_2, ∂_3, ∂_4 and ∂_5 are the parameters of the model, ε_t is the disturbance term.

3.3 ARDL Model Specification

Therefore, following Pesaran et al., (2001), equation 4 was subsequently transformed into an ARDL model along with its restricted error correction (ECT) version in equations 6 and 7, respectively. As a result, the study's ARDL model is specified as in equation 6.

$$\Delta ln(GDP)_t = a_0 + a_1 \ln(GDP)_{t-1} + a_2(\text{CO2})_{t-1} + a_3(\text{DCPS})_{t-1} + a_4(\text{GFCF})_{t-1} + a_5\ln(\text{TOPN})_{t-1} + a_6\ln(\text{FDI})_{t-1} + \sum_{i=1}^{p} \beta_1 \Delta\, ln(GDP)_{t-i} + \sum_{i=0}^{q} \beta_2 \Delta \ln(CO2)_{t-i} + \sum_{i=0}^{r} \beta_3 \Delta(DCPS)_{t-i} + \sum_{i=0}^{s} \beta_4 \Delta(GFCF)_{t-i} + \sum_{i=0}^{t} \beta_5 \Delta \ln(TOPN)_{t-i} + \sum_{i=0}^{u} \beta_6 \Delta\, ln(FDI)_{t-i} + \mu_t \quad (6)$$

Where: $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ *and* β_6 are short-run parameters estimated, Δ denotes first difference, ln means logarithm and p, *q*, *r*, *s t*, *u* are the optimal lag length for the short-run ARDL model.
To obtain the short-run coefficients, we specified and estimated the following ARDL-ECM:

$$\Delta ln(GDP)_t = \sum_{i=1}^{p} \beta_1 \Delta\, ln(GDP)_{t-i} + \sum_{i=0}^{q} \beta_2 \Delta \ln(CO2)_{t-i} + \sum_{i=0}^{r} \beta_3 \Delta(DCPS)_{t-i} + \sum_{i=0}^{s} \beta_4 \Delta(GFCF)_{t-i} + \sum_{i=0}^{t} \beta_5 \Delta \ln(TOPN)_{t-i} + \sum_{i=0}^{u} \beta_6 \Delta\, ln(FDI)_{t-i} + \beta_7\, ECT_{t-1} + \mu_t \quad (7)$$

Where: β_7 is the coefficient of correction term ECT_{t-1} in the ECM-ARDL model specified in equation 6. It is important to note that ECT_{t-1} represents the long-run dynamics of all the variables attached to the coefficients $a_1 - a_6$ in equation 6.
The ARDL bounds test for cointegration offers a unique approach to examining the long-run relationships between variables compared to traditional cointegration tests like Engle-Granger, Johansen, and Johansen-Juselius. Unlike these conventional methods, the ARDL approach does not impose any restrictions on the order of integration of the variables. This flexibility allows it to be applied to a wider range of scenarios, including those where variables are I(0), I(1), or mutually cointegrated. Additionally, the ARDL test can be effectively utilized with small sample sizes, as low as thirty observations, and can simultaneously generate both long-run and short-run coefficients (Pesaran et al., 2011).

3.4 Toda-Yamamoto (1995) Approach to Causality

Due to the potential for biased and invalid results with traditional causality tests when variables exhibit mixed integration orders, the Toda-Yamamoto (T-Y) approach (Toda & Yamamoto, 1995) was employed to investigate the causal relationship between remittances and financial sector development. The T-Y approach offers a robust alternative by estimating a VAR model in levels and testing general restrictions on the parameter matrices, regardless of the integration order of the variables. Essentially a modified Engle-Granger causality test, the T-Y approach utilizes a modified Wald (MWald) test within an augmented VAR model (Toda & Yamamoto, 1995). The T-Y procedure involves determining the optimal VAR order (k) using AIC, SBC, and HQC information criteria. Following optimal lag order determination, Toda and Yamamoto (1995) recommend estimating a VAR(k+dmax) model, where dmax represents the maximum order of integration capturing the data generation process. To test for causality among CO2, financial development (credit to the private sector), capital formation, and other variables within the T-Y framework, a bi-variate VAR(k) model is specified:

$$\Delta lnGDP_t = \omega_X + \sum_{i=1}^{k+m} \in_x \Delta lnGDP_{t-1} + \sum_{i=1}^{k+m} \tau_x \Delta CO2_{t-1} + \mu_{tx} \quad (8)$$

$$\Delta CO2_t = \omega_y + \sum_{i=1}^{k+m} \in_y \Delta CO2_{t-1} + \sum_{i=1}^{k+m} \tau_y \Delta lnGDP_{t-1} + \mu_{ty} \quad (9)$$

$$\Delta DCPS_t = \omega_X + \sum_{i=1}^{k+m} \in_x \Delta DCPS_{t-1} + \sum_{i=1}^{k+m} \tau_x \Delta lnGDP_{t-1} + \mu_{tx} \quad (10)$$

$$\Delta GFCF_t = \omega_y + \sum_{i=1}^{k+m} \in_y \Delta GFCF_{t-1} + \sum_{i=1}^{k+m} \tau_y \Delta lnGDP_{t-1} + \mu_{ty} \quad (11)$$

$$\Delta lnTOPN_t = \omega_X + \sum_{i=1}^{k+m} \in_x \Delta lnTOPN_{t-1} + \sum_{i=1}^{k+m} \tau_x \Delta lnGDP_{t-1} + \mu_{tx} \quad (12)$$

$$\Delta FDI_t = \omega_X + \sum_{i=1}^{k+m} \in_x \Delta FDI_{t-1} + \sum_{i=1}^{k+m} \tau_x \Delta lnGDP_{t-1} + \mu_{ty} \quad (13)$$

The Toda-Yamamoto causality analysis employed in equations 7-12 utilizes a first-difference operator (Δ) to examine the relationship between variables. The maximum order of integration (k) determines the number of times a variable is differenced to achieve stationarity. The optimal lag length (m) is determined using a lag selection method. Intercepts (ω_X and ω_y) represent constants, while coefficients (∈_x and ∈_y) represent the estimated relationships between variables.

To determine the direction of causality, the following decision criteria are applied:

i. Unidirectional causality: A statistically significant coefficient for lnGDP indicates unidirectional causality from lnGDP to CO2 emissions. Conversely, a statistically significant coefficient for CO2 emissions suggests unidirectional causality from CO2 emissions to lnGDP.

ii. Bidirectional causality: Statistically significant coefficients for both lnGDP and CO2 emissions imply bidirectional causality, indicating that both variables influence each other.

iii. Independent or neutral causality: Statistically insignificant coefficients for both lnGDP and CO2 emissions suggest independent or neutral causality, indicating that there is no significant relationship between the two variables. These decision criteria are applied to all variables in equations 8, 9, 10, 11, 12, and 13 of the study's models.

3.5 Sources of Data

This research utilized time series data from the World Bank’s Global Data Facility (WDI). The dataset consisted of variables such as carbon dioxide emissions (CO2) measured in metric tons per capita, per capita real GDP (GDPC) as a gauge of economic growth, trade openness (TPOPN) expressed as the percentage of exports and imports relative to GDP, domestic credit to the private sector (DCPS), gross fixed capital formation (GFCF), and information on foreign direct investment (FDI) collected from WDI. The data spanned from 1991 to 2021.

3.6 Description and measurement of Variables

Economic growth, as measured by Real Gross Domestic Product (GDP) adjusted for inflation, serves as the dependent variable in this analysis. GDP encompasses the total value generated by all resident producers within an economy, inclusive of product taxes and exclusive of subsidies not reflected in the product's value. This calculation omits the depreciation of manufactured assets and the depletion and degradation of natural resources (World Bank, 2023). Carbon dioxide emissions (CO2) from solid fuel consumption primarily stem from coal combustion as an energy source (World Bank, 2023). Foreign direct investment represents the net inflow of investments aimed at establishing a significant and enduring management stake (comprising 10 per cent or more of voting stock) in an enterprise operating within a different economy than that of the investor. It encompasses the combined inflows of equity capital, reinvested earnings, other long-term capital, and short-term capital, as reported in the balance of payments (World Bank, 2023).
Trade openness is the sum of service exports and imports, divided by the value of GDP, all calculated in current U.S. dollars, representing trade in services (World Bank, 2023). Gross Fixed Capital Formation (GFCF), previously known as Gross Domestic Fixed Investment, measures investments made in improving the land, acquiring plant and machinery, constructing infrastructure, and building structures such as schools, offices, hospitals, private residences, and commercial and industrial establishments (World Bank, 2023). Financial resources provided to the private sector by banks and other depository corporations, excluding central banks, are referred to as domestic credit to the private sector, also known as DCPS (WDI, 2023). These resources include loans, purchases of non-equity securities, trade credits, and other accounts receivable that create a claim for repayment. In some cases, these claims may also include credit extended to public enterprises.

4. Data Presentation and Analysis

4.1 Descriptive Statistics

Table 1 Descriptive Statistics

Variables	Mean	Std.Dev	Min	Max
GDP	261725.6	65040.6	199039.2	385349
CO_2	112.1475	84.89753	7.334	370.367
FDI	1.717021	1.324847	-1.150856	5.790847
TOPN	33.82655	0.506077	2.212206	3.975523
DCPS	2.185181	4.312285	1.600906	3.104107
GFCF	2.467117	6.250091	1.697265	3.561650
Obs.	**30**	**30**	**30**	**30**

Source: Author’s Computations

Table 1 presents descriptive statistics for six variables: gross domestic product (GDP), carbon dioxide emissions (CO2), foreign direct investment (FDI), trade openness (TOPN), domestic credit to the private sector (DCPS), and gross fixed capital formation (GFCF). GDP is a measure of a country's total output of goods and services. The mean GDP in the sample is 261,725.6, with a standard deviation of 65,040.6. The minimum and maximum GDP values are 199,039.2 and 385,349, respectively. CO2 emissions are a measure of the amount of carbon dioxide released into the atmosphere. The mean CO2 emissions in the sample is 112.15, with a standard deviation of 84.89. The minimum and maximum CO2 emissions values are 7.33 and 370.37, respectively. FDI is a measure of the investment made by one country in another country. The mean FDI in the sample is 1.72, with a standard deviation of 1.32. The minimum and maximum FDI values are -1.15 and 5.79, respectively. TOPN is a measure of a country's openness to trade. The mean TOPN in the sample is 33.83, with a standard deviation of 0.51. The minimum and maximum TOPN values are 2.21 and 3.98, respectively. DCPS is a measure of the amount of credit that is available to the private sector. The mean DCPS in the sample is 2.19, with a standard deviation of 4.31. The minimum and maximum DCPS values are 1.60 and 3.10, respectively. GFCF is a measure of the investment that is made in fixed capital, such as buildings and machinery. The mean GFCF in the sample is 2.47, with a standard deviation of 6.25. The minimum and maximum GFCF values are 1.69 and 3.56, respectively.

Table 2. Correlation Matrix for the six variables

Variables	GDP	CO2	FDI	TOPN	DCPS	GFCF
GDP	1.00					
CO_2	0.15	1.00				
FDI	0.85	0.20	1.00			
TOPN	0.70	0.10	0.65	1.00		
DCPS	0.60	0.05	0.50	0.75	1.00	
GFCF	0.55	0.00	0.45	0.70	0.85	1.00

Source: Author’s Computations

The correlation matrix depicts the intensity and direction of the linear association between variables. A correlation coefficient of 1.0 signifies a perfect positive correlation, while -1.0 denotes a perfect negative correlation. A coefficient of 0.0 indicates no linear relationship. The correlation matrix unveils robust positive correlations between all variables, implying that they tend to move in the same direction. For example, nations with higher GDP also exhibit higher CO2 emissions, FDI, TOPN, DCPS, and GFCF.

4.2 Results of Unit Root Test

To assess the time series characteristics and ascertain the stationarity and order of integration of the data, a unit root test was performed. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were employed to analyze the unit root. The findings, as presented in Table 4, reveal that all variables, except FDI, exhibit a unit root at the level. This suggests that these variables, excluding FDI, are non-stationary at the level. However, upon taking the first difference, all variables achieve stationarity. Consequently, it can be inferred that all variables, apart from FDI, are integrated into order 1, or I(1).

Table 4 Results of Unit Root Test

	ADF		PP		
Variables	Level	First Difference	Level	First Difference	Stationarity status
GDP	-1.0858	-4.0310*	-0.3667	-4.0395*	I(1)
CO_2	-2.7744***	7.9789*	-2.6004***	11.1825*	I(1)
FDI	-3.7658**	-8.9962*	3.7083**	-13.4362*	I(0)
TOPN	-2.2397	7.9065*	-2.5167	-7.9065*	I(1)
DCPS	-1.5227	-5.1921*	-1.5777	-17.885*	I(1)
GFCF	-1.5569	-3.5284**	-2.9165***	-5.2109*	I(1)

Notes: ***, ** and * denote significance at 1%, 5% and 10% respectively.
Source: Author’s computation

This indicates that the variables are stationary and have no trend. Therefore, they are integrated with order zero I(0) and order I(1). The choice of the ARDL approach in this study is well justified due to the mixed order of integration of the variables.

4.3 Bounds Test Approach for Cointegration

Table 5 Cointegration Result

Dependent Variables		Functions		F-Statistics	
LGDP		**F(LGDP/ CO_2, FDI, DCPS, GFCF, TOPN)**		**4.763422*****	
Critical Values Bounds					
10%		5%		1%	
I(0)	I(1)	1(0)	I(1)	1(1)	I(0)
2.2	3.09	2.56	3.49	3.29	4.37

Notes: ***, ** and * denote significance at 1%, 5% and 10% respectively.
Source: Author's compilation

After verifying that the variables were stationary, a cointegration test was performed using the bounds testing approach. The results, presented in Table 5, indicate that the F-statistic for the function F(LGDP/LCO2, LFDI, LCRED, LINV, LOPN) is 4.763422, surpassing the upper critical bound at the 1% significance level. This suggests that there is evidence of cointegration between LGDP and the other variables, implying a long-term relationship among GDP, CO2 emissions, FDI, domestic credit to the private sector, capital formation, and trade openness.

4.4 Results of Selected Short run Model

Based on the Akaike Information Criterion (AIC), an optimal lag duration of (3,4,4,4,4,4,4) is recommended. The findings reveal a statistically significant positive correlation between emissions and economic growth in the short run, with a p-value of less than 1%.

Table 6 Estimated short-run coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNGDP(-1))	-0.2767	0.1175	-2.3548	0.0652
D(LNGDP(-2))	-0.2676	0.0765	-3.4946	0.0174
D(CO_2)	0.0466	0.0047	9.8964	0.0002
D(CO_2 (-1))	-0.1189	0.0106	-11.1814	0.0001
D(CO_2 (-2))	-0.0583	0.0058	-9.9786	0.0002
D(CO_2 (-3))	-0.0314	0.0050	-6.2795	0.0015
D(FDI)	-0.0061	0.0018	-3.3406	0.0206
D(FDI(-1))	0.0453	0.0046	0.8799	0.0001
D(FDI(-2))	0.0335	0.0029	11.3828	0.0001
D(FDI(-3))	0.0190	0.0025	7.5017	0.0007
D(TOPN)	0.1203	0.0096	12.4914	0.0001
D(TOPN(-1))	-0.1141	0.0094	-12.1078	0.0001
D(TOPN(-2))	-0.0416	0.0118	-3.5314	0.0167
D(TOPN(-3))	-0.0279	0.0098	-2.9529	0.0318
D(GFCF)	-0.0973	0.0178	-5.4645	0.0028
D(GFCF(-1))	0.1750	0.0235	7.4376	0.0007
D(GFCF(-2))	0.0176	0.0185	0.9591	0.3833
D(GFCF(-3))	-0.0876	0.0214	-4.1329	0.0091
D(DCPS)	0.0896	0.0129	8.1293	0.0005
D(DCPS(-1)	-0.1562	0.0179	-9.0508	0.0003
D(DCPS(-2))	-0.0876	0.0189	-6.2205	0.0016

D(DCPS(-3))	-0.0557	0.0157	-4.4522	0.0067
CointEq(-1)*	-0.4244	0.0315	-13.4617	0.0000

Δ is the first difference operator. Source: Author's computation

An econometric analysis was conducted to investigate the factors influencing economic growth. The findings reveal that a 1% increase in carbon emissions leads to a 0.046% increase in economic growth. In the short term, a 1% increase in foreign direct investment (FDI) results in a 0.006% decrease in economic growth. Conversely, a 1% increase in trade openness and domestic lending leads to a 0.120% and 0.089% increase in economic growth, respectively. However, a 1% increase in domestic investment is associated with a 0.097% decrease in economic growth. The results also suggest a short-run to long-run adjustment, indicating that economic growth converges to its equilibrium level within a year.

4.5 Results of Long-run Model

Table 6 Estimated long run coefficient

Levels Equation Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO_2	0.4878	0.121500	4.0150	0.0102
FDI	-0.1566	0.024077	-6.5070	0.0013
TOPN	0.6928	0.120185	5.7647	0.0022
GFCF	-1.0490	0.251556	-4.1701	0.0087
DCPS	0.7008	0.063342	11.0646	0.0001
C	9.3275	0.339082	27.5083	0.0000

Source: Author's compilation (2023)

Table 6 shows the positive coefficient for CO2 indicates that economic growth is associated with higher CO2 emissions. This aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests a U-shaped relationship between economic growth and environmental pollution. Additionally, the positive coefficient for TOPN suggests that trade openness leads to increased CO_2 emissions. This is because trade openness often results in higher production and consumption, both of which contribute to CO_2 emissions. On the other hand, the negative coefficient for GFCF suggests that increased investment is linked to lower CO_2 emissions. This is likely due to the adoption of more efficient technologies resulting from investment, which can help reduce CO_2 emissions. Lastly, the positive coefficient for DCPS indicates that an increase in domestic credit to the private sector is associated with higher CO_2 emissions. This is likely because increased credit leads to higher investment and production, both of which contribute to CO_2 emissions.

4.6 Results of Diagnostic Tests

Table 7 Results of Diagnostic Tests

Test Statistic	Results
Serial Correlation: CHSQ(2;3)	5.4569 [0.1001]
Functional Form: Reset F-stat(1,5)	0.7436 [0.4279]
Normality: Jarque-Bera	0.3006 [0.8604]
Heteroscedasticity: CHSQ(28,5)	0.9442 [0.5963]

Source: Author's compilation (2023)

A comprehensive diagnostic examination was performed to assess the model's robustness and validity. This evaluation encompassed potential issues such as serial correlation, heteroscedasticity, and functional form misspecification. The Jarque-Bera test, with a p-value of 0.1001, yielded a statistic of 5.456947, indicating that the residuals exhibit no signs of non-normality. This implies that the residuals adhere to a multivariate normal distribution, supporting the model's assumption of normally distributed residuals. The heteroskedasticity test yielded a p-value exceeding 5%, along with a statistic of 0.944220. This result suggests that the error terms are free from heteroscedasticity, implying that the model's residual variance remains constant (homoscedastic). The Ramsey Reset F-statistic stood at 0.7436, with a p-value of 0.4279, indicating that the estimated model is free from misspecification issues. However, the serial correlation test revealed the presence of serial correlation among the errors.

4.7 Stability Test

The stability of the long-run parameters was examined using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ). Figures 2 and 3 display the graphs generated from these tests. It can be observed that the plots of CUSUM and CUSUMSQ remain within the critical boundaries, indicating consistency in the model and predicted parameters over time. As a result, the calculated coefficient can be utilized to inform policy-decisions.

Figure 2: Plot of CUSUM

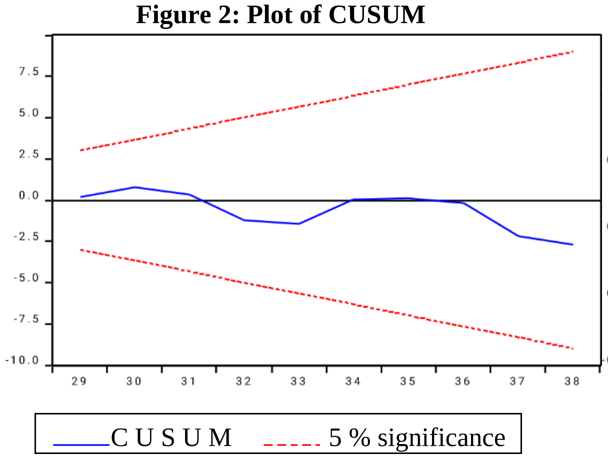
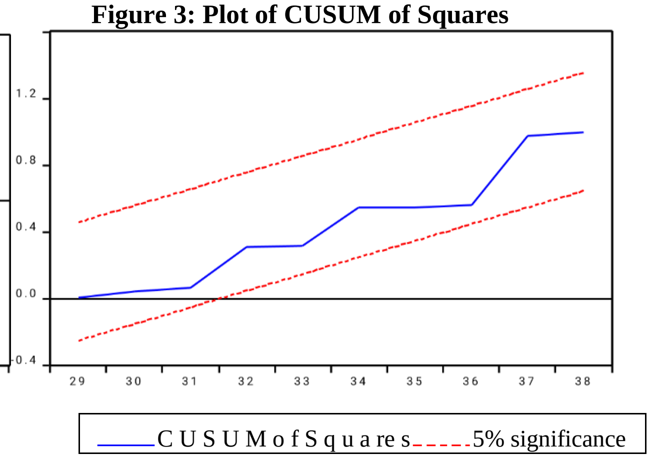


Figure 3: Plot of CUSUM of Squares



4.8 Results of the Causality Test

The study utilized the Toda and Yamamoto (1995) method to determine the causal relationships between CO_2 emissions, financial development, capital formation, and economic growth in Nigeria from 1991 to 2021. The initial tests conducted indicate that the conditions for the T.Y causality test were met.

Table 8: Results of Toda-Yamamoto Causality

Null hypothesis	Df	MWALID	Prob	Decision	Direction of causality
GDP→ CO_2	2	7.027	0.029	Reject	Unidirectional
CO_2→GDP	2	0.464	0.793	Do not reject	No causality
GDP →DCPS	2	6.209	0.001	Reject	Unidirectional
DCPS→GDP	2	3.287	0.093	Reject	Unidirectional
GDP →GFCF	2	11.334	0.008	Reject	Unidirectional
GFCF→GDP	2	8.982	0.022	Reject	Unidirectional
GDP →TOPN	2	0.637	0.727	Do not reject	No causality
TOPN→GDP	2	1.747	0.417	Do not reject	No causality

GDP →FDI	2	0.637	0.727	Do not reject	No causality
FDI→GDP	2	0.559	0.756	Do not reject	No causality

Note: → denotes 'does not Granger cause'; Df indicate degree of freedom and MWALD is the modified Wald chi-square of the Toda-Yamamoto (1995) causality test.
Source: Author's computation (2023)

Table 8 presents the following results regarding the relationship between various variables GDP is a causal factor for CO_2 emissions, DCPS, and GFCF. This means that changes in GDP will lead to changes in these variables, but not the other way around. The Toda-Yamamoto causality test aligns with other studies, (Bekar, 2018; Alege et al. 2016; Ozturk and Uddin, 2012) on the relationship between GDP and these variables. Policymakers should prioritize sustainable economic growth-to reduce CO_2 emissions.

4.9 Summary of the Major Findings

This study delves into the intricate relationship between carbon emissions, financial development, capital formation, and economic growth in Nigeria, employing an autoregressive distributed lag (ARDL) approach to unravel the dynamic interplay between these variables over the period 1991 to 2021. The empirical findings reveal a significant short-term positive association between carbon emissions and economic growth, indicating that a 1% increase in carbon emissions translates into a 0.046% boost in economic growth. However, the study also uncovers a negative impact of foreign direct investment (FDI) on short-term economic growth, while trade openness, domestic credit, and capital formation exert positive influences. Furthermore, the long-run analysis unveils a persistent positive relationship between emissions and economic growth, suggesting that a 1% increase in carbon emissions leads to a 0.48% increase in long-term economic growth. These findings underscore the multifaceted nature of the relationship between carbon emissions and economic growth, highlighting the need for comprehensive policy measures that promote sustainable economic development while mitigating environmental concerns. However, FDI, trade openness, domestic credit, and investment have varying effects on long-run economic growth. These findings are consistent with previous research (Mesagan, 2015; Muftau, Iyoboyi, & Ademola, 2014). However, the second objective of this study involves investigating the causal relationship between CO_2 emissions, financial development, capital formation, and economic growth in Nigeria. The results of the Toda-Yamamoto causality test indicate that GDP has a long-run impact on CO_2 and DCPS, and DCPS and GFCF have a long-run impact on GDP. However, there is no evidence of a long-run impact between GDP and TOPN, FDI, or any other variables. These findings are consistent with previous studies conducted by scholars such as (Bekar 2018; Ozturk & Uddin 2012).

5. Conclusions and Policy Recommendations

Nigeria has seen an increase in CO2 emissions, as well as an increase in financial development, capital formation and economic growth. This study examines the effect of CO2 emissions on financial development, capital formation and growth in Nigeria between 1991 and 2021. The results show that higher CO2 emissions are related to growth. It is important to implement effective policies to support this growth and reduce CO2 emissions. Policy recommendations on the impact of carbon emissions on financial development, capital formation and economic growth in Nigeria:

i. Implement a carbon tax or cap-and-trade system to put a price on carbon emissions and encourage businesses to reduce their emissions. Revenue from this tax can be used to invest in clean energy and other climate-friendly initiatives.

ii. Provide financial incentives such as tax credits, rebates, and low-interest loans to encourage businesses and citizens to invest in clean energy and energy-efficient technologies.
iii. Establish a green bond market to facilitate investment in environmentally friendly projects. Green bonds are debt instruments specifically designed to finance clean energy and other climate-friendly initiatives.
iv. Support the development of financial products and services that promote green investment, such as climate-risk insurance, green mortgages, and green venture capital funds.
v. Strengthen financial sector regulation to incorporate climate risks. This could involve mandating banks and other financial institutions to assess and manage their exposure to climate risk.
vi. Promote financial education and raise awareness about climate risks among businesses and individuals. This will enable them to make well-informed decisions regarding their investments.

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