Examining the link between carbon emission, carbon emission intensity and financial development in Nigeria. A Dynamic ARDL Simulation

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Performed analysis

Abstract

The need for adequate and consistent policies to mitigate the continuous rise of carbon emission have motivated the energy economist in the past decades to actively involved and explore common economic agents that are driving the rising pattern in the environmental pollution. This study is positioned towards contributing to the on-going debates on this issue by exploring the impact of bank credit to the private sector on aggregate carbon emissions and carbon emission intensity in Nigeria over the period 1971– 2016 using dynamic ARDL simulations. Controlling for the influence of fossil energy intensity of consumption and economic globalization, the study found that bank credit to the private sector has a positive significant long-run increasing effect on aggregate CO2 emission and carbon emission intensity in the economy. Second, the estimated coefficients show that fossil energy intensity of consumption and economic globalization have a significant long-run and short-run increasing impact on aggregate CO2 emission and carbon emission intensity in the economy. In contrast, the population has a significant long-run and short-run reducing effect on aggregate CO2 emission and only the long run reducing effect on carbon emission intensity. Third, economic growth has significant short-run and increasing long-run effects on aggregate CO2 emission and a long run increasing effect on carbon emission intensity. In sum, the results show that the economy is yet to transient to renewable energy.

Keywords: Carbon emission, carbon emission intensity, financial development, dynamic ARDL simulation, STIRPAT, Nigeria

Introduction

The collaboration of Intergovernmental Panel on Climate Change (IPCC) affirmed carbon emission as the cause of global warming and climate change in the world (IPCC 2018) and warned that if no drastic action is taken to reduce carbon emissions, the physical impact on climate change on the international economy will be significant. The extractions of natural resources in Africa are mostly carried out with the use of heavy machinery that turns out enormous carbon emission (Kwakwa et al., 2018). The broad use of heavy machinery in industrial sector coupled with expansion of existing firms and springing up of new businesses activities are inimical to the environment quality with challenges of spontaneous rise in carbon emission (Letcher 2020 and Lahiani 2020).

According to International Energy Agency (IEA) 2020, Nigeria had estimated 37bn barrels of untapped crude oil reserves at the end of 2019, which contains 15% of Africa's oil reserves and 16% of its gas. Appendix 1 reveals the total energy usage in Nigeria, this trend showed Biofuels and waste are major sources of energy in Nigeria, which account for about 80% of total primary energy consumed in Nigeria (Ben-Iwo, Manovic and Longhurst, 2016). IEA (2020) data showed that greenhouse gas emissions from fossil fuel production used have increased by 16% since 2015.

Fossil fuel combustion has been the major means of energy generation in the Nigeria economy and have translated into heavy carbon emission. The potential effect of this on climate change is a threat to Nigerian sustainable economic development, by accounting to a projected damage of 6% to 30% of gross domestic product by 2050, this will translate to the loss of US$ 100 to US$ 460 billion if drastic measure are not taken to cushion the effect (Amin et al 2020). Record shows that 2.7% per annum increase in greenhouse gas (GHG) emissions released after three years of landmark Paris Agreement (Le Quéré et al. 2018). The rise in income of households and production activities stimulate economic growth with an intensive demand for heavy technologies and investment in energy intensive sectors (Shoaib et al. 2020; Gill et al. 2019; Liu and Song (2020); Lahiani, 2020). In other words, financial development has the tendency to raise the significant level of carbon emissions either from emerging economies or developing countries (Jiang, Yang and Ma 2019).

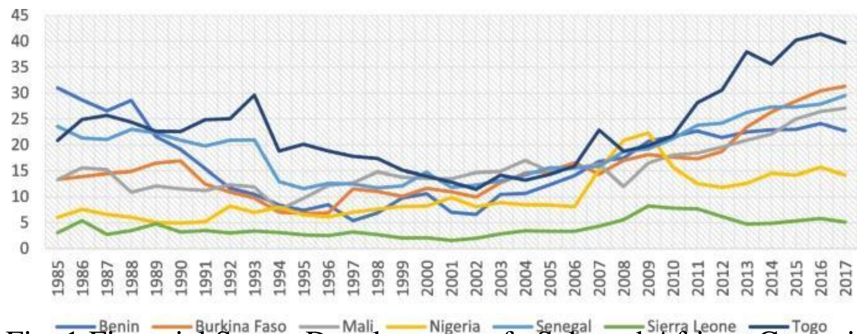


Fig. 1 Financial Sector Development of Selected African Countries

Source: WDI (2019)

Fig.1 shown the level of financial sector development in selected African countries, it can been seen that, Nigeria has a relative development in the financial sector from year 2006 upward, while domestic credit to the private sector as a percentage of GDP averaged 13.03% between 2001 and 2017. In line with the trend, financial development expands production capacity and social development with a significant pressure mounting on the environment (Aye and Edoja, 2017; Danish and Wang, 2019; WWF, 2018). The rising trend of financial development in Nigeria is associated with the steady growing of carbon emission as shown in Fig. 2, the causes yet to be given adequate attention for policy maker. Deepened financial system with more access to credit by households increases income and expansion of firms' production growth. The disbursement of credit to enhance domestic product supply and creating demand for local and international markets depend on the functioning financial market cause by asymmetric macroeconomic variables (Shahbaz, Shahzad, Ahmad and Alam, 2016). Credit facilities to industrialists pave way for entrepreneurs' to acquire more industrial machines with rise in intensity of carbon emission (Xing, Jiang and Ma, 2017). The promotion of consistent burning of fossils fuels by sectors (oil, gas and coal), untamed carbon dioxide (CO2) releasing into the atmosphere thereby wreaking havoc to environmental quality (Johnsson et al. 2019).

Financial development through the financial markets equally enables firms to have access to financial assistance to acquire low carbon emission technologies (Tsaurai, 2019). Financial development plays a pivotal role in allocating financial resources to adopt environment friendly technology by sectors of the economy as well as reducing greenhouse gas emissions at low pace of economic growth (Hao et al. 2016). In view of this, the initiative of development finance under Central Bank of Nigeria engage in policies formulation and implementation towards new products discovery and creating an enabling atmosphere for financial institutions to deliver services in a secure, competitive and sustainable healthy environment in all the sectors of the economy through the Central Bank of Nigeria (Igwebuike, Udeh and Okonkwo, 2019)

The knowledge gap linking carbon emission and carbon emission intensity to financial development in Nigeria motivate the research paper. The depth of financial intermediation in promoting green financing to prevent environmental damage attracted global research interest.

Fig. 2 Carbon Emission: Nigeria Ecological Footprint by Land Type

Data source: Global Footprint Network 2021

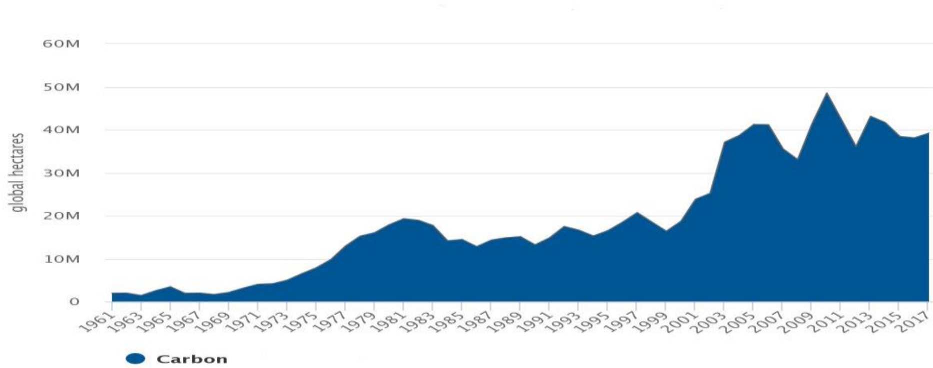


Figure 2: Global Footprint Network 2021

Data source: Global Footprint Network 2021

The financial sector development increase the carbon emission intensity in Nigeria, Fig. 2 shows the rise in carbon emission from year 2001 at its peak. Studies on carbon emission intensity and financial development are still scarce in the existing literature in Nigeria context. The earlier study by (Aminu et al 2020) adopted Auto-Regressive Distributed Lag technique that failed to capture sufficient (STIRPAT) dynamic features, also, (Omoke et al 2020) used nonlinear autoregressive distributed lag (NARDL) framework to analyze Ecological footprint in Nigeria with no measures of population, affluence and technology for adequate projection policy formulation. Studies such as (Adejumo and Asongu 2020; Adejumo 2020; Ali et al. 2019; Ali et al. 2016; Rafindadi 2016; Riti and Shu 2016) used carbon emissions CO2 to measure degradation in Nigeria. The rise in financial sector development along with the carbon emission increase call for urgent attention for environmental sustainability. The components of carbon and non-carbon emissions degradation in environment formed an all-inclusive measure for sustainable environment (Wang and Dong 2019; Danish and Wang 2019). The country-specific insights findings will facilitates and strengthening policy decision given empirical modelling based on the Stochastic Impact by Regression on Population, Affluence, and Technology (STIRPAT) framework that incorporates carbon emission intensity variables and proxy of financial development. The use of (ARDL) simulations model for both short and long run estimates will equally give a better interpretation and policy recommendation on implication of carbon emissions intensity and financial market instruments in Nigeria.

The remainder of this research paper is organized in sections as follows: A brief earlier literature study is discussed in “Literature review” section. Data and methodology are discussed in “Data and methodology” section. Empirical results and discussion are discussed in “Result and discussion” section and finally, the conclusion in the “Conclusions and policy recommendations” section

Theoretical Literature

This section is divided into two: theoretical review and empirical review. The empirical review are encapsulated in two form: the discussion area and the tabular form as sown in table 1 below.

This subject area is currently submerged with empirical entries from different studies adopting a global perspective, regional perspective and national perspective. The seminal work of Kraft & Kraft (1978) is credited to be the first empirical entry as they attempted to establish the link between energy consumption, economic growth and carbon emissions, they concluded that economic growth is associated with substantial energy consumption that induces carbon emissions. Recently, attention has been shifted from economic growth to other variables like financial development.

The channel through which financial development impacts carbon emissions differs from developing economies to developed economies. In developing economies, in pursuance of economic growth and prosperity, financial system’s institutions play a sacrosanct role by extant distribution of funds to investible channels which may not be environmental-friendly ranging from manufacturing firms vis-à-vis its high pollution potential emanating from consistent reliance on traditional energy sources and cheap access to credit to business owners and households enabling them purchase equipment with energy demand. FD in the developing economies’ case through the growth channel increases the level of energy consumption especially from traditional sources, which in turn, increases carbon emissions in developing economies (Sardosky, 2010, Sardosky, 2011, Chang, 2015, Sethi, et al, 2020; Samreen & Majeed, 2020). On the other hand, in the case of developed economies, financial development reduces carbon emissions, firstly through the presence of admirable institutional quality, presence of socially responsible and sophisticated investors and the machinery of bank financial institutions and the stock market collectively engenders investment in green-oriented manufacturing firms with renewable energy-efficient technologies associated with little or no negative environmental effects as opposed to the fossil fuels used in less-developed and developing economies (Samreen & Majeed, 2020, Tahir, et al 2020 and Yao & Tang, 2020). Another school of thought hinged the low C02 emissions in developed economies on the transfer of heavy production plants from developed countries to developing countries where there is a loophole in regulation either tax-based or environment-based by way of foreign direct investment (Shoaib, Rafique, Nadeem & Huang, 2019).

Examining the carbon intensity-financial development nexus, there are two notable channels through which financial development can affect carbon emissions intensity other than economic growth and development channel as recognized in (Hao, et al. 2016, Pan, et al., 2016 and Vujovic, et al., 2018). The second channel will definitely differ from developing economies to developed economies, financial development can assist developing countries in reducing carbon emissions intensity through supporting the adoption of low-carbon energy technologies by way of copy-manufacture from developed economies. However, in developed economies, financial development reduces carbon emissions intensity by actively funding research and development activities to decipher numerous low-carbon technologies to support existing technologies (Hao, et al. 2016, Li & Ouyang, 2019 and Shoaib, et al. 2019). The third channel relies on the discretion of financial institutions and their level of social responsibility reflected in their provision of sophisticated financial assistance and services to green-oriented firms at lower costs (Li & Ouyang, 2019).

Other stream of literature established positive linkage between environmental degradation indicators and financial development are numerous; such as the work of Shahzad et al, 2017 who employed Autoregressive Distributive Lag model on time series data covering the period of covering 1971–2011 to investigate the association among carbon emission, bank credit and energy use in Pakistan. Their result revealed a direct association between credit to private sector and carbon dioxide emission and between trade openness and CO_2. Further findings indicated a non-linear association between the variables. In like manner, Zhang and Zhao, 2019 employed GMM in an STIRPAT framework on data ranging from 1996-2015 to examine the linkage between social development and environmental pollution in 30 provinces of China and found that R&D

investment exerted positive influence on CO_2. It was also revealed that a two-way causal-effect existed between financial development index and CO_2. Also, analyzing the influence of GDP per capita, energy use, foreign investment, and bank credit to private sectors on environmental quality in Kuwait with data spanning 1980 - 2013, Salahuddin *et al*, 2018 adopted ARDL bound test and observed that FDI, per capita GDP, financial development and electricity use exerted direct and significant impact on CO_2 emission in the country. A case study of eight Asian nations employed FMOLS technique on data covering the period of 1982 to 2017 to analyze the effect of energy use and domestic credit to private sector on CO_2 emission and found that bank credit, fossil fuel, and urbanization have direct linkage with CO_2 emissions while trade openness reduces CO_2 in the nations under study (Abbasi, *et al*, 2020). A similar study was carried out by Tahir *et al*, 2020 in South Asian countries with same econometric approach on longitudinal data covering the period of 1990 - 2014 and the result showed that domestic credit (as financial development indicator), energy use, and GDP have positive impact on carbon emission. It was also revealed that globalization reduces CO_2 in the region.

The effect of energy mix and financial development on environmental degradation was explored by Ali et al (2019) in Nigeria. Utilizing ARDL approach on time series data spanning 1971 to 2010, they found that at both long and short run periods, credit to private sector exerted direct and significant influence on CO_2 emission. It was equally found that GDP and energy use have direct linkage with CO_2 in the long run but exhibit inverse association with CO_2 in the short period. Yasin et al. (2020) exploring the association among domestic credit to private sector, political institution, energy use and environmental degradation in a pool of 59 less developed nations with data covering 1996 to 2016, adopted GMM and EGLS techniques and found that CPS, urbanization and electricity use have direct influence on CO_2 in lower-income nations. The study further validates the EKC hypothesis. A similar study was also conducted by Yasin, Ahmad, and Chaudhary, 2020, who proxied environmental quality with ecological foot print and grouping 110 nations into high-income and low-income countries, using same GMM model on data spanning 1996 to 2016, they found that financial development and energy use increase ecological foot print in high-income nations while urban population, trade openness and political institution have inverse influence on ecological footprint. Pooling 17 emerging nations to explore the effect of disaggregated bank development indices on ecological foot print with data ranging from 1991 – 2013, Destek, 2019, adopted panel regression approach and the findings showed that bank credit and stock returns mitigates pollution while no significant linkage was seen between banking development, bond market development and ecological foot print. Utilizing non-linear ARDL technique on data spanning 1971 to 2014 in Nigeria, Omoke *et al*, 2020 found that rise in financial development exert inverse influences on ecological footprint but a decrease in financial development escalates ecological foot print in Nigeria. It was also revealed that GDP, energy use, urban populace, and globalization positively contribute to ecological foot print in Nigeria.

Second strand of literature confirms that the relationship between banking credit and carbon dioxide emission is indirect in nature. Example is the work of Zaidi *et al*, 2019 who examined the connectivity among globalization, domestic credit to private sector and carbon emissions for the APEC nations and employing Westerlund cointegration technique on data spanning 1990 – 2016 found an inverse association between domestic credit and CO2. Further findings indicated that globalization reduces CO2 while confirming the presence of EKC hypothesis in APEC nations. A study in Pakistan on the linkages among domestic credit, energy use, economic growth and carbon emission utilized simulated ARDL on data covering the period of 1982-2018 and found that while financial development, foreign direct investment, real GDP and energy use raise level of CO2 emission, domestic credit reduces it (Khan, Teng, and Khan, 2020). Employing same technique in Chinese 30-provinces on data spanning 1997 - 2016, Guo and Hu, 2020 established an inverse association between stock returns and CO2 emission. The indirect influence of financial development on of environmental degradation indicator entails that China is successful in giving out its credits or financial facilities to sponsor environmental friendly projects. Thus, such projects will lead to trading on cost-efficient energy technology such as investment in business vehicles and real estate term loans which is more of low-carbon finance Nwani and Omoke (2020) employed STIRPAT on the ARDL framework to examine the association between bank credit and low-carbon emission in Brazil with data spanning 1971 to 2014. The findings of their study revealed that credit to private sector promotes low-carbon emission since inverse linkage existed between them. Utilizing the same econometric technique on data spanning 1992 - 2014, Tian et al, 2017 analyzed the impact of domestic credit to private sector on CO2 intensity in China and their result showed the existence of cointegrating relationship between the variables. Also, they found that both innovation and domestic credit have inverse influence on carbon intensity while poor correlation existed between stock returns and carbon emission/GDP intensity.

The third strand of literature found mixed results on the association between carbon dioxide emission and financial developments. To start with, Ibrahim, 2018 explored the linkage between foreign trade, domestic credit and CO_2 emission intensity in middle-income nations with data ranging from 1991–2010. Employing the EKC framework, their findings showed that financial development reduces carbon emission intensity in upper middle-income nations and Europe while exacerbates pollution in Europe. A case study of Chinese provinces on the linkage between bank credit and carbon dioxide utilized panel cointegrating techniques (FMOLS, DOLS and PVECM) on data covering the period of 2001-2015 and observed that financial development exerted direct influence on CO_2 in some provinces and inverse impact on CO_2 in other provinces (Zhao and Yang, 2020). Considering the effect bank credit to private sector on environmental quality in G and N-countries, Zafar et al, 2019, employed cointegration method and established that financial development indictor reduces CO_2 in G-7 nations while it raises CO_2 in N-11 nations. The study validates the EKC hypothesis. The findings also showed a two-way causality existing between fd index and carbon dioxide emission. A study in Chinese provinces and national economy, employed spatial panel models on data ranging from 2007 to 2016 and found that financial development at provincial level and population raises carbon intensity while at national level, the linkage was inverse (Liu and Song, 2020). Shahbaz *et al,* 2020 employed an EKC on ARDL framework to explore the environmental effect of economic growth, financial development and research and development expenses for the UK with data spanning 1970 - 2017. Their findings validated the EKC hypothesis.

The fourth strand of literature proved that there was no linkage between domestic credit to private sector and environmental degradation based on the level of significance. For instance; Lu, 2018 analyzed the influence of electricity use and bank credit on carbon emissions in 12 Asian developing nations with longitudinal data data spanning 1993–2013. Adopting panel cointegration technique, the study found that the bank credit had no significant effect environmental quality while GDP and energy use exerted direct influence on CO_2 emission. In same manner, Chen et al, 2019 adopted DSUR method on data spanning 1980 to 2016 in the examination of the influence of domestic credit, energy sources on carbon dioxide emission in Central Eastern European nations and found no significant linkage between credit to private sector and carbon dioxide emission. However, they established that globalization and both energy sources increased CO_2.

Another strand of literature reinforces that activities of construction firms, manufacturing firms and raw materials suppliers for construction can contribute to an increase in carbon emissions other than financial development as widely discussed in academic literature. C02 emissions generate more impact on the environment and one of the main polluting industries is that of cement and its components. Asides financial development, population, urbanization and industrialization also contributes to increase in carbon emissions in developing economies already substantiated with vast empirical evidences (Nag & Parikh, 2000). But more differently, construction and manufacturing activities also contributes greatly to environmental degradation apart from financial development if mismanaged and by-products are not immersed as a raw material in creating other common construction materials (Carvalho, et al, 2014; Mendes, et al 2019 and Azevedo, et al 2019). Elaborating further on the environmental impacts of cement production and other building components; Azevedo, et al (2019) confirmed that application of locally manufactured ceramic materials for civil construction contributes to environmental degradation as wastes are discarded directly into host environment. In similar vein, the processing of ornamental stones in Brazil increases environmental pollution as each operational stage of ornamental stone processing generates a considerable amount of sludge wastes which if not channeled into re-production of another finished good will constitute environmental nuisance (Carvalho, et al 2014). A more practical example of recycling wastes into more acceptable and environmental-friendly finished goods is seen in the experiment carried out by Carvalho, et al (2014); where sludge waste generated from the cutting process of granite and limestone were dried and crushed in a media alongside a type CPII 32 cement to produce soil-cement blocks. The heavy reliance on traditional fossil fuels for production and the poor handling of raw material sources (disposing and extracting) sums up the negative effects of cement production and its various alternatives on its host environment (Amaral, et al 2019). Further fears of environmental pollution is heightened in the case of increasing iron-ore production owing to mass storage of by-products (tailings) in dams which most times ruptures and amount to leakages to its host environment, a feasible solution still resides in reusing the wastes to produce materials for constructive purposes to reduce environmental damage (Zhao, et al, 2014 and Mendes, et al 2019).

Table 1 shows the summary of empirical reviews and related findings.

Table 1: Summary of selected empirical literature

s/n	Authors	Sample and period	Methodology	Results
1	Sethi, Chakrabarti,and Bhattacharjee (2020)	India (1980–2015)	ARDL	Globalization, per capita GDP and energy use stimulates CO2 emission
2	Salahuddin, Gow and Ozturk (2015)	GCC nations (1980–2012.)	Panel FMOLS and DOLS	GDP and electricity intensity exert positive significant influence on environmental degradation indicator in the long-period while there exist no significant short-run relationship among them.
3	Xie et al (2020)	5 BRICS countries (1996 - 2015)	Panel FMOLS and DOLS	Public debt securities make reduces carbon emission while private credit hinders increases co2
4	Shen, et al (2020).	30 Chinese provinces(1995-2017)	CS-ARDL	Natural resources rent and financial development have a positive influence carbon dioxide
5	Paramati, Mo and Huang (2020).	25 OECD countries (1991–2016)	FMOLS	per capita income and financial deepening exert a direct impact on environmental quality while FDI and openness reduce CO2
6	Wang, Vo,, Shahbaz and Ak (2020).	G7 -Nations (1996–2017)	CS-ARDL	FD and natural resources have direct association with CO2 while Agriculture value added has inverse relationship with carbon emission
7	Trinks, Mulder, and Scholtens (2020).	1572 int'l firms(2009–2017)	DDF-DEA model	Financial development index influences CO2 inversely.
8	Katircioğlu and Taşpinar(2017)	Turkey (1960-2010)	DOLS	Financial development has inverse linkage with carbon emission. Also, there is evidence of EKC hypothesis in Turkey.
9	Kim, Wu, and Lin (2020)	Advance and developing nations (1989–2013)	EKC model	Validates the existence of Kuznet hypothesis
10	Ashraf, et al (2020)	34 S.A manufacturing firms(2005 - 2012)	Probit Regression	Financial slack has a direct effect on carbon performance.
11	Amin, Dogan, and Khan (2020).	ten countries (1980 -2014)	Quintile Regression	Existence of inverted U-shape relationship. Also financial development indicators reduces carbon emission.

12	Charfeddine and Kahia (2019).	24 Nations-MENA Region (1980 -2015)	PVAR	Renewable energy and financial development have negative and significant effect on CO2
13	Kayani, Ashfaq and Siddiqu (2020).	10 emitter nations(1990-2016)	PFMOLS and VECM	Financial development and urbanization exert positive significant influence on CO2. renewable energy has inverse impact on Carbon dioxide while no significant association between Globalization and Co2
14	Khan, Peng and Li. (2019).	193 Nations (1990–2017)	SUR, 3-Stage LS and system GMM	Financial development reduces CO2 while energy consumption and economic growth increase Co2
15	Saud, Chen and Haseeb (2020).	OBOR-initiative nations(1990-2014)	FMOLS	Financial development, energy consumption, economic growth, and trade positively affects ecological footprint, while globalization reduces ecological footprint.
16	Huang and Zhao (2018).	30 provinces in China (2000-2014)	extended STIRPAT and GMM	A U-shaped association between EXC and the per capita income. various financial indicators reduced CO2 emissions embodied in exports
17	Lin and Agyeman (2020).	47 SSA nations (1980 - 2014)	ARDL	Fossil fuel energy intensity and other energy sources have inverse influence on carbon emission
18	Brouwers, Schoubben, and Hulle (2018).	European Union Emission Trading Scheme (2005–2012)	fixed effect instrumental variables	Financial development exhibit direct effect on environmental quality.
19	Khan, Ju, Latif and Khan (2020).	Pakistan (1990 - 2015)	ARDL	Access to Electricity, Financial development, and population growth have a positive relationship with CO2 emission. Natural resources shows insignificant relationship with CO2 emission
20	Gokmenoglu,Taspinar and Rahman (2020).	Turkey (1960-2010)	FMOLS	Financial development exert negative impact on both CO2 and ecological footprint. Military expenditure and economic growth have positive influence on environmental degradation indicators.

21	Dar and Asif (2017).	India (1971–2013)	ARDL	ARDL reveal that there is no long run equilibrium association among the variables. Energy use has a positive impact on carbon emissions. EKC was no established. Financial development and energy consumption increased CO2.
22	Asumadu-Sarkodie and Owusu (2016).	Sri Lanka (1971 to 2012)	ARDL	Financial development and industrialization exert positive influence on CO2 while GDP and population have negative effect on CO2
23	Ahmad, Khan, Rahman and Khan (2018).	China (1980–2014)	NARDL	Energy use, economic growth and financial development have positive and significant impact on environmental degradation.
24	Gokmenoglu and Sadeghieh (2019).	Turkey	Johansen co-integration test and ECM	Economic growth and credit to private sector reduces CO2 while fuel consumption increases CO2 in Turkey.

Model and methodology

The IPAT model was suggested by Ehrlich and Holdren (1971) as a paradigm, whereby economic activities affect greenhouse emissions and thus lead to environmental pollution. A basic environmental effect equation is therefore in the form:

$$I = PAT \tag{1}$$

I mean environmental effects, P means population, A means affluence, and T represents technology. Therefore, the IPAT model describes the impact of human activities on the environment as a function of income/affluence, population, and technology (York et al. 2003). Therefore, the IPAT model explains the environmental effect of human activities on the environment as a function of income, population, and technology (York et al. 2003).In line with IPAT projections, Dietz and Rosa (1994) have suggested the stochastic impact on population, affluence, and technology (STIRPAT) by regression to help the statistical test conditions. The model STIRPAT is represented as:

$$I = aP^bA^cT^d\varepsilon \tag{2}$$

The above model identifies a,b,c and as scales exponents of P,A, and T respectively. ε is the white noise and the is shown in log-form below using the standard STIRPAT model is given as:

$$lnI = lna + b(lnP) + c(\ln A) + d(\ln T) + \varepsilon \tag{3}$$

In the aforementioned, b, c and d describe the predicted environmental impact innovation in the selected explanatory variable by 1 percent change, if the remaining other determinant factors remain unchanged. Using technology (T) in Equation 3, other variables' effect could be captured in STIRPAT model (see, Dietz and Rosa 1994). Several new studies have expanded the STIRPAT model to explore other factors' effect (Huang and Zhao, 2018; Zhang and Zhao, 2019; Nwani and Omoke, 2020). The STIRPAT model is expanded to include the effects on the private sector of domestic credit by banks in line with the intent of this study. The STIRPAT extended model takes shape:

$$lnI = \alpha_0 + \alpha_1(lnP) + \alpha_2(\ln A) + \alpha_3(\ln Fossil) + \alpha_3(ln\, Pcrsg) + \alpha_3(ln\, Ecge) + \varepsilon \tag{4}$$

Where,

lnI represents the environmental impact of carbon dioxide emissions. This study employs two variables such as: aggregate carbon dioxide emissions (CO2) and carbon emission per unit of gross domestic product (lnCEI) to extend the understanding of the level environmental challenges from the activities of the financial system. These variables can either be measured as metric tons per capita denoted by CO2 (see, Zhang and Zhao, 2019; Shahzad *et al*, 2017; Abbasi, *et al*, 2020; and Ali *et al*, 2019, etc.), or as carbon emission per unit of gross domestic product denoted by Carbon emission intensity (CEI) (see Nwani and Omoke, 2020; Ibrahim, 2018; Liu and Song, 2020 etc). lnP is the population, $(\ln A)$ is economic growth, $\ln Fossil$ is fossil energy consumption GDP per capita, $ln\, Pcrsg$ is the financial development, $ln\, Ecge$ is the globalization index, ε is the stochastic error term. All the variables are sources from World Bank Indicators from the period of 1972 to 2016.

Financial development is one of the major explanatory variable measured by the domestic credit to private sector as a percentage of GDP. Bank credits to business firms can lead to increase in production and technological progress via purchase of heavy machines which in turn emits carbon into the environment causing degradation of the atmosphere or credits to private sector will enable business expansion which will lead to economic growth and then to air pollution from machines (see, and it has been incorporated in the works of Omoke et al, 2020; Yasin, Ahmad, and Chaudhary, 2020; Destek, 2019; Zaidi *et al*, 2019, etc. However, it has been posited credit to private sector influences carbon emissions by business effect, consumer and technological influence.

Gross domestic product is used to proxy Affluence. It represents the economic growth calculated as real GDP per capita that is, at constant 2000 US dollars. Rising economic growth due to economic activities lead to high energy demand and demand for energy consuming goods which in turn leads to environmental pollution as a result of carbon emission and this has been adopted in various literatures (see Salahuddin *et al*, 2018; Saud, Chen and Haseeb, 2020; Gokmenoglu and Sadeghieh, 2019; Tahir *et al*, 2020). Economic growth brings about increase in energy consumption which leads to carbon dioxide emissions (AhAtil et al, 2019).

Population is measured as the total number of people living in and area over a specified time period. It is one of our major independent variables. Theoretically, there has been two perspective of literature on the linkage between population and carbon dioxide emission such as; i). Ecological theory of modernization which posit positive relationship between modernization or population and CO2 emission and II). The urbanization transition theory which predicts that population has neutral effect on CO2 emission (Khan et al, 2020). This has been adopted by Asumadu-Sarkodie and Owusu. 2016; Khan, Ju, Latif and Khan, 2020, etc).

Controlling for the influence of fossil energy intensity and globalization index for robust analysis. We used fossil energy consumption intensity calculated as aggregates of oil, coal, and natural gas consumptions in million tonnes of oil equivalent per real GDP. Recent studies have also adopted it (such as, Liu and Song, 2020; Shahzad et al, 2017; Lin and Agyeman, 2020; Guo and Hu, 2020 etc.). Globalization through free trade and capital increases production and boosts economic growth which in turn hamper the environmental quality via carbon dioxide emission due to increase in energy demand and consumption. So directly or indirectly, it contributes to environmental hazards by scale effect, composition and technological influence. (Shahbaz et al. 2016) and it has been incorporated in empirical studies (see Abbasi, *et al*, 2020; Saud, Chen and Haseeb, 2020; Kayani, Ashfaq and Siddiqu, 2020, etc.). It is also one of the control variables for this study. The detail explanations are highlighted in table 2.

The ARDL-bounds cointegration test

The long run association among the variables in equation 4 is investigated using the autoregressive distributed lag model (ARDL) known as bound testing. The technique is the most favored approach of literature co-integration considering its econometrics advantages such as; it offers robust and reliable estimates in both small and large samples, ii) it is the most acceptable technique as long as none of the variables is integration of order I(2). (iii) It offers tools for the derivation of short and long-term model estimates when cointégration among variables is verified (Pesaran et al. 2001). The empirical formula of the ARDL model is based on the log-linear specification in Equation 4 and it is provided in Equations (5) and (6) for carbon dioxide (CO2) and carbon intensity (CEI) aggregates, respectively

$$\begin{aligned}\Delta lnCO2_t = a_0 &+ \sum_{i=1}^{p} a_{1i}\Delta lnCO2_{t-1} + \sum_{i=1}^{p} a_{2i}\Delta lnP_{2t-1} + \sum_{i=1}^{p} a_{3i}\Delta lnA_{3t-1} + \sum_{i=1}^{p} a_{4i}\Delta lnFossil_{4t-1} \\ &+ \sum_{i=1}^{p} a_{5i}\Delta lnPcsrg_{5t-1} + \sum_{i=1}^{p} a_{6i}\Delta lnEcge_{6t-1} + a_7 lnCO2_{t-1} + a_8 lnP_{t-1} + a_9 lnA_{t-1} \\ &+ a_{10} lnFossil_{t-1} + a_{11} lnPcsrg_{t-1} + a_{12} lnEcge_{t-1} + a_D lnTBrk_{t-1} + \varepsilon_t \qquad (5)\end{aligned}$$

$$\Delta lnCEI_t = b_0 + \sum_{i=1}^{p} b_{1i}\Delta lnCEI_{t-1} + \sum_{i=1}^{p} b_{2i}\Delta lnP_{2t-1} + \sum_{i=1}^{p} b_{3i}\Delta lnA_{3t-1} + \sum_{i=1}^{p} b_{4i}\Delta lnFossil_{4t-1}$$
$$+ \sum_{i=1}^{p} b_{5i}\Delta lnPcsrg_{5t-1} + \sum_{i=1}^{p} b_{6i}\Delta lnEcge_{6t-1} + b_7 lnCO2_{t-1} + b_8 lnP_{t-1} + b_9 lnA_{t-1}$$
$$+ b_{10} lnFossil_{t-1} + b_{11} lnPcsrg_{t-1} + b_{12} lnEcge_{t-1} + b_D lnTBrk_{t-1} + \varepsilon_t \quad (6)$$

Regression on equation (5) & (6) produce F and T statistics that is used for testing the null hypothesis of no cointegration among the variables $H_0: a_7 = a_8 = a_9 = a_{10} = a_{11} = a_{12} = 0$; $H_0: b_7 = b_8 = b_9 = b_{10} = b_{11} = b_{12} = 0$. The effect of structural breaks (TBrk) is represented as a_D and b_D in Equation (5) & (6) respectively. Using the most recent and reliable critical values for F and T statistics as proposed by Kripfganz and Schneider (2019), and the corresponding approximated p values to evaluate the already stated null hypothesis. Cointegration decision is made by comparing approximate F and T statistics to upper and lower critical values as thus, if the probability value is less than 0.10 in the F and T statistical, the null hypothesis of no cointegration is rejected.

The error correction model is captured in Equations (7) and (8) respectively, identifying the short-run dynamics in the association among the variables.

$$\Delta lnCO2_t = a_0 + \sum_{i=1}^{p} a_{1i}\Delta lnCO2_{t-1} + \sum_{i=1}^{p} a_{2i}\Delta lnP_{2t-1} + \sum_{i=1}^{p} a_{3i}\Delta lnA_{3t-1} + \sum_{i=1}^{p} a_{4i}\Delta lnFossil_{4t-1}$$
$$+ \sum_{i=1}^{p} a_{5i}\Delta lnPcsrg_{5t-1} + \sum_{i=1}^{p} a_{6i}\Delta lnEcge_{6t-1} + \lambda_2 ecm_{t-1} + \varepsilon_t \quad (7)$$

$$\Delta lnCEI_t = a_0 + \sum_{i=1}^{p} a_{1i}\Delta lnCEI_{t-1} + \sum_{i=1}^{p} a_{2i}\Delta lnP_{2t-1} + \sum_{i=1}^{p} a_{3i}\Delta lnA_{3t-1} + \sum_{i=1}^{p} a_{4i}\Delta lnFossil_{4t-1}$$
$$+ \sum_{i=1}^{p} a_{5i}\Delta lnPcsrg_{5t-1} + \sum_{i=1}^{p} a_{6i}\Delta lnEcge_{6t-1} + \lambda_1 ecm_{t-1} + \varepsilon_t \quad (8)$$

The dynamic simulations of using ARDL framework

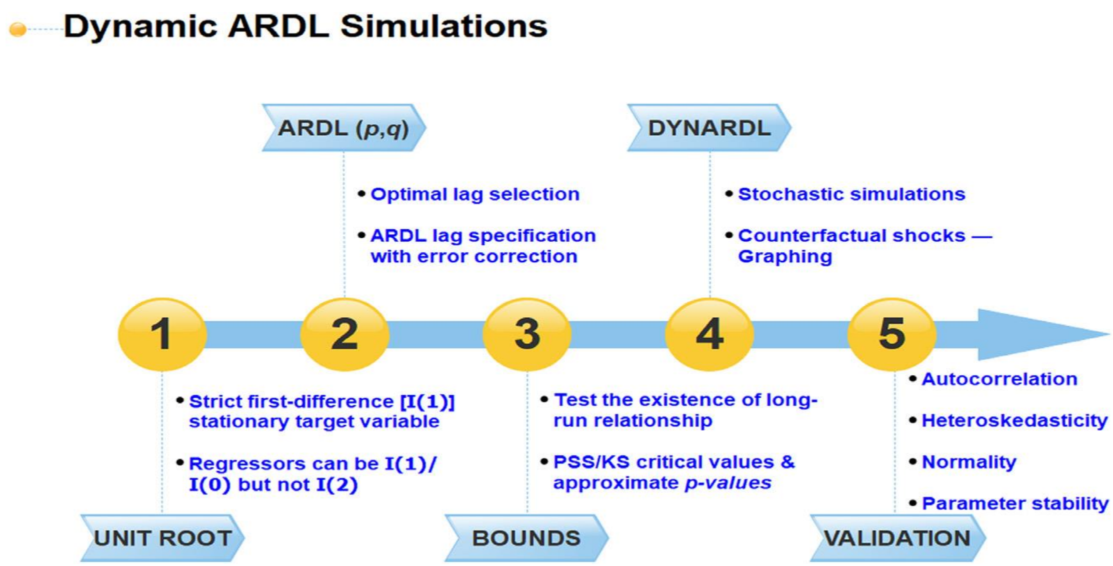


Figure 3: Econometric steps in the application of Dynamic ARDL Simulation

Sources: Sarkodie and Owusu (2020)

The novel dynamic ARDL Simulation was introduced by (Jordan and Philips 2018) and credited for solving the traditional ARDL model's problems in examining the long-run and short-run model specifications. According to Sarkodie and Owusu (2020), the dynamic simulated ARDL model can stimulate, estimate, and automatically plots to predict graphs of negative and positive changes in the variables and their short and long-run relationships robotically. The application of this model follows some econometric protocol, as shown in (figure 3). First, the ARDL bounds testing procedure used in the novel dynamic ARDL simulations requires a strict first-difference stationary, I (1) dependent variable (Jordan and Philips 2018). This implies that the dependent variable must be non-stationary at the level I (0) to apply cointegration. Second, bounds testing procedure with a dependent variable violating the initial conditions can be tested using the standard but modified ARDL bounds test with surface regression (Kripfganz and Schneider 2019). Several unit root tests can be employed to test this conditional requirement, such as augmented Dickey-Fuller (ADF), Phillips-Perron (PP), among others. Third, all sampled independent variables can either be I (0) or integrated of order one, I (1) but not greater than I (1) devoid of a structural break, autocorrelation, and heteroskedasticity. They are represented as thus:

$$\Delta lnCO2_t = a_0 + \psi_0 lnCO2_{t-1} + \varphi_1 \Delta lnP_t + \psi_1 lnP_{t-1} + \varphi_2 \Delta lnA_t + \psi_2 lnA_{t-1} + \varphi_3 \Delta lnFossil_t + \psi_3 lnFossil_{t-1} + \varphi_4 \Delta lnPcsrg_t + \psi_4 lnFossil_{t-1} + \varphi_5 \Delta lnEcge_t + \psi_5 lnEcge_{t-1} + \varepsilon_t \quad (9)$$

$$\Delta lnCEI_t = b_0 + \pi_0 lnCEI_{t-1} + \theta_1 \Delta lnP_t + \pi_1 lnP_{t-1} + \theta_2 \Delta lnA_t + \pi_2 lnA_{t-1} + \theta_3 \Delta lnFossil_t + \pi_3 lnFossil_{t-1} + \theta_4 \Delta lnPcsrg_t + \pi_4 lnFossil_{t-1} + \theta_5 \Delta lnEcge_t + \pi_5 lnEcge_{t-1} + \varepsilon_t \quad (10)$$

Using the dynamic ARDL error correction term algorithm for Equation (9) and (10), 5,000 simulations are performed from a multivariate normal distribution. Two specific criteria must be met before implementation to ensure accurate and reliable simulation estimates. Based on these criteria, it considers the following preliminary steps. First, unit-root analysis measures the order integration among the variables to ensure that none of the variables has a unit root. Second, a Pesaran et al. (2001)-based ARDL-bound test is implemented to determine whether cointegration among variables exists. Confirmation of co-integration is a requirement for the implementation of dynamic simulations of the mentioned ARDL models.

Table 2: Definition and description of variables

Definitions	Variables	Mean	Median	Max	Min	Std. Dev.	Skew	Kurt	sources
CO2 emissions (kg per 2010 US$ of GDP)	CEI	0.37945	0.35285	0.6455	0.22613	0.11649	0.63195	2.4380	WBDI
CO2 emissions (kt)	CO2	71474.3	67056.6	131685.	32280.6	29819.6	0.51647	2.0409	WBDI
Population, total	P	1.10E+0	1.04E+0	1.86E+0	5.73E+0	3.77E+0	4.03E-01	2.01E+0	WBDI
GDP per capita (constant 2010 US$)	A	1786.88	1766.48	2563.9	1324.29	395.246	0.41122	1.8940	WBDI
Fossil energy consumption in Mtoe to GDP constant 2010 US$	Fossil	17.9801	18.9523	22.8447	5.96777	4.01972	-1.61442	4.9441	WBDI
Index of economic globalization de jure (KOFEcGIdj)	Ecge	46.5492	45.7333	55.6326	37.5074	4.81495	-0.06171	2.2393	KOF

WBDI = the World Bank Development Indicators, (Available online: https://databank.worldbank. org/home.aspx); KOF globalization index computed by Gygli et al. (2019) Available online: https://kof.ethz.ch/en/forecasts-andindicators/indicators/kof-globalisation-index.html

Figure 4: Line plot of the variables from 1971 to 2016. Sources see in Table 2 above

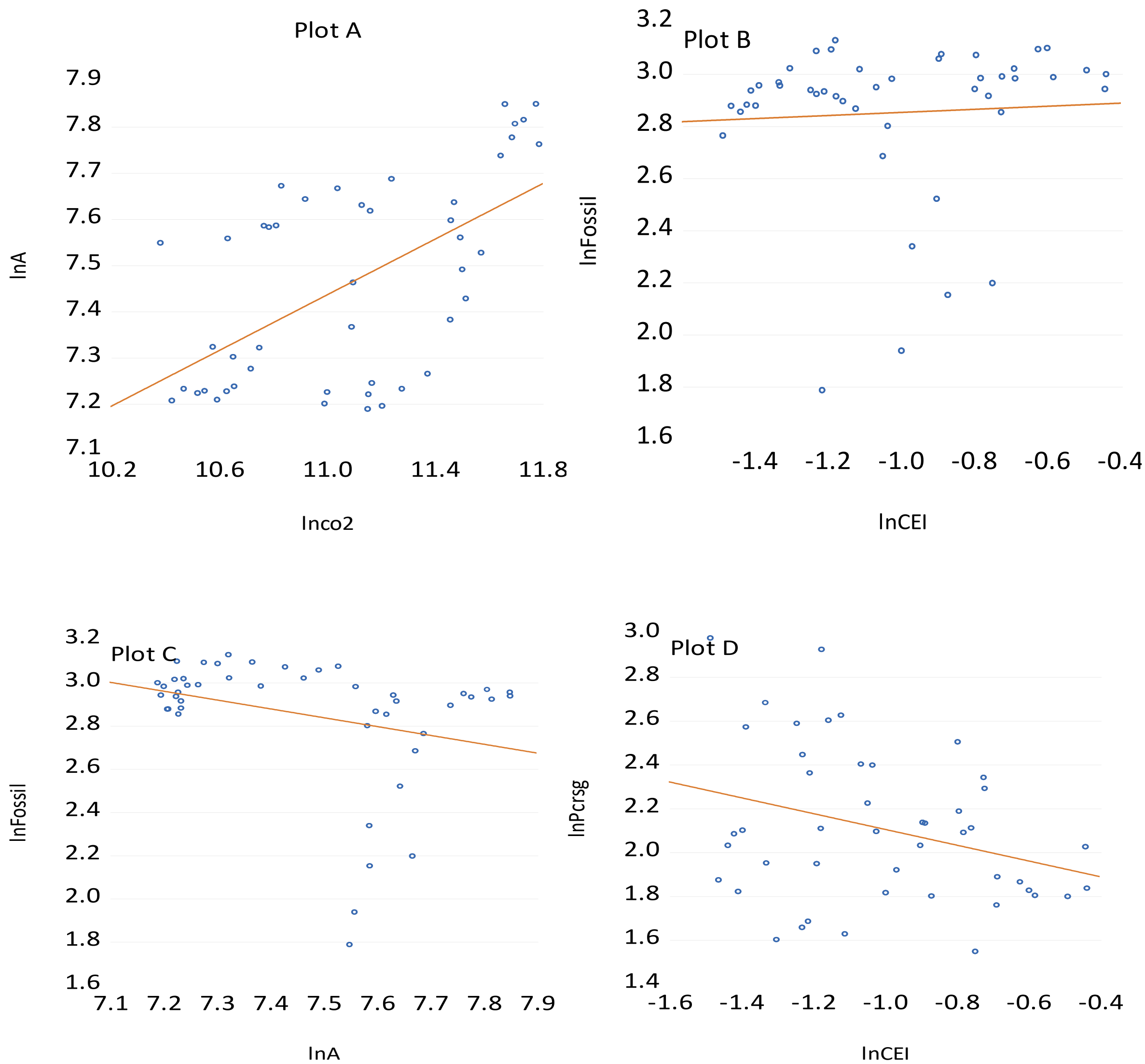


Figure 5: Scatter plots showing the partial correlations of the variables the study

Preliminary investigation

Figure 4 shows the time evolution of the selected the variables from 1971 to 2016, while figure 5 shows the partial correlation between the key variables of interest, and the financial development in Nigeria. Plot A shows a strong positive correlations exists between affluence (lnA) and emissions (lnCO2). Plot B shows that the partial correlation between carbon emission intensity ln(CEI) and fossil fuel consumption is positive. Plot C follows negative correlation between lnA and lnFossil. In sum Plots A, and B show that the energy consumption trend and economic structure in Nigeria could lead carbon intensive activities. Considering the negative correlation between the amount of CO2 emitted per unit of output ln(CEI) and the domestic credit to the private sector by banks, it therefore subject investigation into whether there is any significant relationship leading energy transition exist between bank credit to the private sector carbon emission in Nigeria economy.

Table 3: Traditional unit root ADF

	Level form I(0)			First difference I(1)				
Variables	t-statistics	p-value	break date	t-statistics	p-value	break date	Decision	Result
lnCEI	-2.6716	0.2527	.-	-6.7107***	0.0000	.-	Reject	I(1) at 1%
lnCO2	-2.0933	0.5354	.-	-7.1173***	0.0000	.-	Reject	I(1) at 1%
lnP	-4.1621**	0.0117	.-	-8.2699***	0.0000	.-	Reject	I(0) at 5%
lnA	-1.3979	0.8455	.-	-4.9815***	0.0011	.-	Reject	I(1) at 5%
lnPcrsg	-2.7466	0.2239	.-	-4.4133***	0.0058	.-	Reject	I(1) at 1%
lnFossil	-3.2174	0.0946	.-	-5.3377***	0.0004	.-	Reject	I(1) at 1%
lnEcge	-2.8234	0.1968	.-	-5.4863***	0.0003	.-	Reject	I(1) at 1%

Note:. ** & *** indicate significance at 5% and 1% levels respectively

In table 3, to obtain the stationarity states of the variables of our model, we performed the traditional unit root test of Augmented Dickey-Fuller test (ADF), and the Lee and Strazicich (2003) Lagrange multiplier (LM). The ADF test examines the time series properties without accounting for structural changes in the series but the second test does. Thus, both test reveal mixed stationarity. That is, ADF test indicate that lnCEI (log of carbon emission intensity), lnCO2 (log of carbon dioxide emission), lnPcrsg (log of private sector credit), lnFossil (log of fossil energy) and lnEcge (log of economic globalization) were found the first difference stationary, which implies the presence of unit root in the data while lnP (log of total population) and lnA (log of GDP per capita) have no unit root and as such they are stationary at level. On the other hand, in the table 4, the Lee and Strazicich (2003) Lagrange multiplier (LM) test shows that lnCEI, lnCO2, lnP and lnEcge are all stationary at level while lnA, lnPcrsg and lnfossil are only stationary when difference at first difference.

Table 4: Unit root with two structural break: Lee Strazicich LM unit root test

	Level form I(0)			First difference I(1)			
variables	t-statistics	break date	Result	t-statistics	break date	Decision	Result
lnCEI	-7.2326***	1987 1999	I(0)	-7.2225***	1981 1990	Reject	I(0)
lnCO2	-6.2208**	1987 1998	I(0)	-7.7487***	1981 1995	Reject	I(0)
lnP	-18.412**	1983 2002	I(0)	-18.593**	1982 1987	Reject	I(0)
lnA	-5.0419	1990 2010	I(1)	-6.6623**	1991 2007	Reject	I(1)
lnPcrsg	-5.3276	1984 1988	I(1)	-6.9498**	1981 2006	Reject	I(1)
lnFossil	-5.1474	1992 2009	I(1)	-6.9698**	1981 2008	Reject	I(1)
lnEcge	-7.0857**	1987 2003	I(0)	-7.2967***	1987 2007	Reject	I(0)

Note:. ** & *** indicate significance at 5% and 1% levels respectively

ARDL-bounds test for cointegration

Table 5 shows the implementation of ARDL bounds test for cointegration that explores the long-run relationship among environmental indicators (lnCO2, lnCEI), and the following explanatory variables: population (lnP), affluence (lnA), fossil energy intensity of consumption (lnFossil), domestic credit to the private sector (lnFcrsg), and economic globalization (lnEcge). Kripfganz and Schneider (2019) provide P value, critical values, and the computed F and T statistics at the lower side of table 5. The optimum lags are based on the Akaike Information Criterion (AIC) and the presence of dummy variable is evidence of structural break in the system. The results show that calculated F and T have a significance level and are more than upper critical values I(1) at 1% level for both specifications, while the P values are below 0.001 ($p < 0.001$). On the basis of these figures, in both specification suggesting co-integrating environmental indicators (CO2, CEI), population (P), income (A), fossil energy intensity (fossil), domestic credit to the private sector (Pcrsg), and economic globalization (Ecge) in Nigeria, the null of no co-integration hypothesis between the variables was denied. The two model from the ARDL do not have any econometric misspecifications, serial correlations, heteroscedasticity, non-normality, when subjected to various kinds of diagnostic test such as; Breush-Godfrey LM, Breusch-Pagan Godfrey, ARCH, Ramsey RESET, and Jarque-Bera (see table 5). Figure 6 and 7 are used to test the long run structural stability test using the CUSUM and CUSUMSQ test statistics as prescribed by Brown et al. (1975) and there is evidence of stability over the selected period in the two specification.

Table 5: ARDL-bounds cointegration test and diagnostic result

Model	Optimal Lag selection	K	TBrk	F statistics	t statistics
$lnCO2 = f\{lnP, lnA, lnPcrsg, lnFossil, lnEcge\}$	AIC = 2	5	1987 1998	8.7994***	-6.8605***
Diagnostic Tests:					
Jarque-Bera Normality test	2.3601[0.3072]				
BG serial correlation LM test	0.9329[0.3341]				
Heteroskedasticity test: ARCH effect	0.2893[0.5907]				
Ramsey RESET test	1.9014[0.1797]				
Durbin-Watson statistic	2.2033				
$lnCEI = f\{lnP, lnA, lnPcrsg, lnFossil, lnEcge\}$	AIC = 2	5	1987 1999	6.3082***	-5.7467***
Diagnostic Tests:					
Jarque-Bera Normality test	2.7839[0.2485]				
BG serial correlation LM test	3.9902[0.1360]				
Heteroskedasticity test: ARCH effect	2.1261[0.1448]				
Ramsey RESET test	0.6335[0.5317]				
Durbin-Watson statistic	1.9034				
Critical values and P values					

Source: Kripfganz and Schneider (2018)	10%	5%	1%	p-value
F test: I(0)	2.453	2.954	4.143	0.0000
F test: I(1)	3.739	4.405	5.974	0.0000
T test: I(0)	− 2.515	-2.870	-3.593	0.0000
T test: I(1)	-3.823	-4.246	-5.101	0.0000

Note: The asterisks * and ** indicate 1% and 5% significance levels, respectively based on the critical values generated by the bound testing procedure. Akaike information criteria (AIC) is the optimal lag length. The F-statistic follows the asymptotic critical bounds, which is generated from the Kripfganz and Schneider (2019) procedure.

Table 6: Estimates for Carbon emission intensity (lnCo2)

	ARDL					Dynamic ARDL		
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.
Panel A: short-run estimate								
ecm (-1)	-0.4636***	0.1112	-4.1696	0.0003	-0.4391***	0.1165	-3.7700	0.0010
ΔlnP	-2.5471	71.943	-0.4107	0.6845	-1.5487**	35.399	-2.9300	0.0060
ΔlnA	2.1524***	0.5806	3.7071	0.001	2.0801***	0.5872	3.5400	0.0010
ΔlnPcrsg	-0.0090	0.1293	-0.0699	0.9448	-0.0348	0.1351	-0.2600	0.7990
ΔlnFossil	1.2387**	0.3839	3.2271	0.0033	0.9226**	0.3809	2.4200	0.0210
ΔlnEcg	2.4425***	0.5739	4.2563	0.0002	2.0042***	0.5537	3.6200	0.0010
Δ (TBrk)	-0.3049**	0.1170	-2.6063	0.0147	-0.2635**	0.1197	-2.2000	0.0350
Panel B: long run coefficients								
C	521.581	413.841	1.2603	0.2183	4.3883	2.8204	1.5600	0.1300
lnP	-2.9362	23.0889	-1.2099	0.2368	-0.7527**	0.2618	-2.8800	0.0070
lnA	2.2852***	0.6176	3.7003	0.001	0.9504**	0.3846	2.4700	0.0190
lnFossil	1.0864	0.6454	1.6835	0.1038	0.4375***	0.2102	2.0800	0.0460
lnPcrsg	0.7940**	0.3383	2.3471	0.0265	0.2391*	0.1404	1.7000	0.0990
lnEcge	5.2686	1.2750	4.1323	0.0003	2.1466**	0.6590	3.2600	0.0030
Adj. R squared	0.893				0.7292			
Simulations					5000			
P-value of F stat	0.0000				0.0000			

Note: * and ** respectively show significance at 1% and 5% levels.

Table 7: Estimates for Carbon emission intensity (lnCEI)

	ARDL				Dynamic ARDL			
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.
Panel A: short-run estimate								
ecm(-1)	-0.4062***	0.1044	-3.8925	0.0006	-0.3673***	0.1097	-3.3500	0.0020
ΔlnP	-1.2676	66.9147	-0.2431	0.8097	-1.3662**	32.986	-3.2500	0.0030
ΔlnA	0.9542	0.5454	1.7497	0.0911	0.9091	0.5559	1.6400	0.1120
ΔlnPcrsg	0.0151	0.1195	0.1260	0.9006	0.0441	0.1266	0.3500	0.7300
ΔlnFossil	1.3763**	0.3573	3.8515	0.0006	1.0418**	0.3536	2.9500	0.0060
ΔlnEcg	1.4461**	0.5284	2.7369	0.0107	1.3973**	0.5049	2.7700	0.0090
Δ (TBrk)	-0.1511	0.1139	-1.3267	0.1953	-0.1422	0.1189	-1.2000	0.2410
Panel B: long run coefficients								
c	129.798	419.048	0.3097	0.7590	9.6053**	2.9302	3.2800	0.0030
lnP	-8.7053	23.3800	-0.3723	0.7124	-1.0047**	0.3087	-3.2500	0.0030
lnA	1.7908**	0.6422	2.7886	0.0094	0.5587*	0.2913	1.9200	0.0640
lnFossil	0.8008**	0.3553	2.2541	0.0322	0.4751**	0.1962	2.4200	0.0220
lnPcrsg	1.9659**	0.6541	3.0055	0.0055	0.2725**	0.1311	2.0800	0.0460
lnEcg	3.5599**	1.1811	3.0141	0.0054	1.3613**	0.6534	2.0800	0.0460
Adj. R squared	0.8287				0.7559			
Simulations					5000			
P-value of F-stat	0.0000				0.000			

Note: * and ** respectively show significance at 1% and 5% levels.

Dynamic ARDL simulation results

For comparative analysis, we started by applying the traditional ARDL analysis and then followed by the dynamic ARDL model simulations. The empirical evidence in Table 6 & 7 confirm the presence of common relationship in terms positive or negative signs between the endogenous and exogenous variables, however, their measurements varies. To provide a robust estimates, a multivariable normal distribution vector is provided by 5000 simulations. Table 6 &7 show the model estimates of aggregate carbon dioxide (CO2) emission and carbon emission intensity (CEI) respectively. The dynamic ARDL simulations observed at 10 times point with positive or negative 10 percent innovations on each of the exogenous variables in the model reflect graphical representation in figures 8,9,10,11, 12, 13 and 14 to cause counterfactual changes in the independent. Table 6 we found that bank credit to the private sector (lnPcrsg) is positively linked to carbon emissions in the long run at the 10% level. This implies that (lnPcrsg) plays a significant role in increasing carbon emissions. All other being equal, a 1% increase in bank credit to the private sector leads carbon emissions by 0.2391%. However in the short run, bank credit to the private sector (lnPcrsg) is statistically insignificant. Figure 8 indicates the impact of positive or negative 10% change in predicted lnPcrsg on lnCO2. A positive 10% change in the first graph produced an insignificant influence in lnCO2 in the short-run, however, the influence shows a significant increase in the predicted long-run value. In the second graph a negative 10% change produced an insignificant rise in lnCO2 in the short-run. The long-run influence has a significant increase in the predicted value, but the influence in the long run decreased. Thus, positive change is high compared to the effect of negative change in lnCO2.

Similarly in Table 7, bank credit to the private sector (lnPcrsg) increases carbon intensity in the long run. All else equal, 0.27% of carbon intensity is led by 1% increase in bank credit to the private sector. However, bank credit to the private sector (lnPcrsg) is statistically insignificant in the short run. Figure 9 indicates the influence of positive or negative 10% change in predicted lnPcrsg on lnCEI. In the first graph a positive 10% change produced an insignificant influence on carbon intensity in the short-run, however, the impact shows a significant increase in the predicted long-run value. Conversely, the second graph shows that a negative 10% change produced an insignificant increase in carbon intensity in the short-run. In the long-run, the value had a significant increase in the predicted value, but the effect in the long run decrease. Thus, the impact of positive change is high compared to the impact of negative change in carbon intensity. Therefore, financial development is attached to negative environmental consequences as it creates more carbon emissions. This implies that financial development harms the environment by incrementing financial channels, increasing investments in new projects, (Haseeb et al. 2018). Indeed, the growing level of CO2 emissions is corroborated with the findings (Asumadu-Sarkodie and Owusu, 2016, Shen et al. 2020, Khan, Ju, Latif and Khan 2020, Saud, Chen and Haseeb, 2020).

The empirical results for long-run impact of population, economic growth, fossil consumption power intensity and economic globalization are reported in table 6. The impact of population on carbon emissions (lnCO2) is negative and significant. This shows that population is declining carbon emissions. It implies that population is associated with higher income levels which serve as a determinant factors in demanding a friendly ecosystem that reduces carbon emission. Keeping other factors constant, 1% increase in lnP lowers carbon emissions by 1.5% in the short-run and 0.75 percent in the long-run. Economic growth (affluence) is positively linked to carbon emissions (lnCO2) at 1 percent level. It implies that a 1% increase in economic growth may lead carbon emissions by 2.0801 percent in the short-run and 0.9504 percent in the long-run keeping all else the same.

We found evidence of inverted U-shaped relationship between carbon emission and economic growth by comparing the short-run and long-run economic growth, the long-run effect of economic growth is found to be smaller than the short-run impact. This result is consistent with Narayan and Narayan (2010), who predicted the EKC hypothesis through the same procedure. Figure 10 explains the effect of 10 positive and negative shocks on aggregate CO2 emissions (lnCO2) in expected economic growth value (lnA). The first graph shows that positive 10% shocks created a substantial short-run increase in aggregate CO2 emissions, and the effect stayed unchanged in the long-run. A negative 10% innovation is linked to positive effect in short-run aggregate CO2 emissions, and the influence in long-run value produced a significant increase in the expected value. Even, long-term impact decreased.

In table 6, fossil energy intensity of consumption increases aggregate CO2 emissions significantly at 1% level of significance. A 0.9226% and 0.4375% of aggregate CO2 emissions is increased due to 1% rise in fossil energy intensity of consumption in the short-run and long-run leading to environmental degradation through high carbon emissions. This findings is in consonance with the conclusion from Lin and Agyeman (2020). Figure 11 shows how positive and negative 10% innovation in the predicted value of lnFossil impact lnCO2. The positive shock of fossil energy is stable in the long term, even though it increases CO2 emissions in the short term. On the other hand, the negative shocks in lnfossil produced a significant positive impact on aggregate carbon emissions in the short-run and the effect in the long run remained stable and unchanged.

In Table 7, shows the short-run and long-run positive effect of lnfossil on carbon emission intensity at 1% level. It implies that a 1% increase in lnfossil may lead carbon emission intensity by 1.048% in the short-run and by 0.4751% in the long-run keeping all else unchanged. Figure 12 reveals the positive and negative shocks in lnfossil resulting to a changes carbon emission intensity (lnCEI). In the first plot, the positive shock of lnfossil is stable in the long run, even though it increases carbon emission intensity in the short term, while the second plot produced a significant positive impact on carbon emission intensity in the short-run. The effect also had a significant predicted long-run value. Figure 13 indicates the positive and negative changes in economic globalization and its impact on Nigeria's CO2 emissions. 10% positive change in economic globalization suggests a positive effect on the CO2 emissions in Nigeria both in the short run and in the long run. This could be attribute to the rising trade and investment activities, leading to a higher amount of energy usage required in the production and consumption activities, which eventually release more carbon dioxide into the environment. Meanwhile, a 10% negative change in economic globalization indicates a positive effect on CO2 emissions in the short run. In the long run, CO2 emissions decrease with a decrease in economic globalization. Overall the estimates from this empirical study regarding the impact of economic growth and fossil energy consumption align with the theoretical expectations and existing empirical findings. Past empirical entries such as Letcher (2020) believed that the rise of carbon dioxide in the atmosphere is as a result of increased activities from economic growth and fossil energy consumption. For instance, a long-run decrease in the CO2 emissions could be from a decrease in the economic globalization.

The deviation from the short run equilibrium is corrected through the negative and statistical significant of the coefficient of ecm (-1) in both specifications. In Table 6, the coefficient -0.4391 indicates that approximately 43.91% of short-run deviation converges to a long run stable state.

Table 7 shows that the significant negative coefficient suggests that roughly 37 percent of a short-term disequilibrium is reversed to the long run in the carbon emission intensity model.

Conclusion and policy implication

The world has undergone a significant increase in carbon dioxide emissions, which harm the living conditions for the households. This tremendous concern for environmental pollution has led academics and environmental policymakers to focus on this issue to find suitable solutions and implement convenient policies. In this study, we contribute to the existing literature on the link between financial development and CO2 emissions. This study drew insight from the case of Nigeria by exploring the impact of bank credit to private sector on carbon emission over the period of 1971 to 2016. The model incorporated the impact of fossil energy intensity of consumption, bank credit to the private sector and economic globalization in the Stochastic Impact Regress on Population, Affluence and Technology (STIRPAT) Framework. In the analysis, the ARDL test confirmed the long-run equilibrium of these parameters over the sampled period in Nigeria. Using the dynamic ARDL model simulations, the results found are as follows: First, implication of the positive association between financial development and carbon dioxide in Nigeria can be attributed to the fact that availability of financial facilities stimulates expansion of economic activities which brings about high demand for energy consumption-goods that causes carbon dioxide emission in turn. This findings support the assertion by Al-Mulali, Saboori, and Ozturk. 2015, who observed that bank credits make possible loan facilities which encourages high demand for luxury goods and energy consumption goods and as such leads to air pollution by means of CO2 emission. Also, this should be guide to policy makers to make policies that are environmental friendly by advising the financial sectors to pursue giving loans to low-carbon projects and investment. Financial stability is a long term goal and that is why it is not significant in the short period. Direct relationship between GDP per capita and environmental degradation could be linked to the assertion that rise GDP entails rise in national income, and when this happens in a nation, the country will be in danger of high pollution especially when there is lack of energy conservation policy. This implies that Nigeria still uses obsolete equipment and relies heavily on non-renewable energy sources which causes the GHS emission thereby degrading the environment. In order to produce and at same time maintain environmental quality, government should encourage manufacturing industries by subsidizing the use of energy efficient equipment in production. Energy intensity having positive influence on CO2 implies that Nigeria relies heavily on non-renewable energy sources such as coal and other energy sources which emits greenhouse gasses because of its emerging economy nature. It is due to infant industries in the country using obsolete and poor energy consumption technology that hampers the environment. Government can achieve tackle this problem by making subsidies available on low carbon technologies to encourage the use of renewable energy technology and as same time impose high tax on fossil fuel consumption in Nigeria beyond a certain threshold. this relationship is necessitated developing economies like Nigeria will find it very hard to stop energy use since it is the key input for production of goods and services such as; services industries, home utilities whose actions emits carbon into the environment. This outcome corroborates the findings of Haseeb et al. (2018) for and BRICS, Shahbaz et al. (2018) for Japan. Thus government should strive for the enhancement of energy efficiency via advanced and energy-efficient technologies. Positive linkage between globalization and CO2 emission indicates that Nigeria has not been able to attract high technological investment from abroad which provides access to advanced energy-efficient technologies which will help reduce carbon emission.

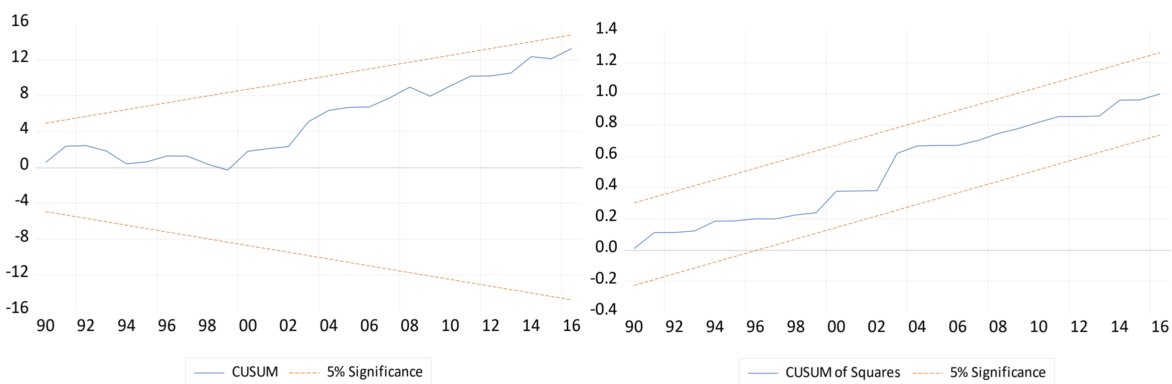


Figure 6: Equation 7 - CUSUM and CUSUMSQ for CO2

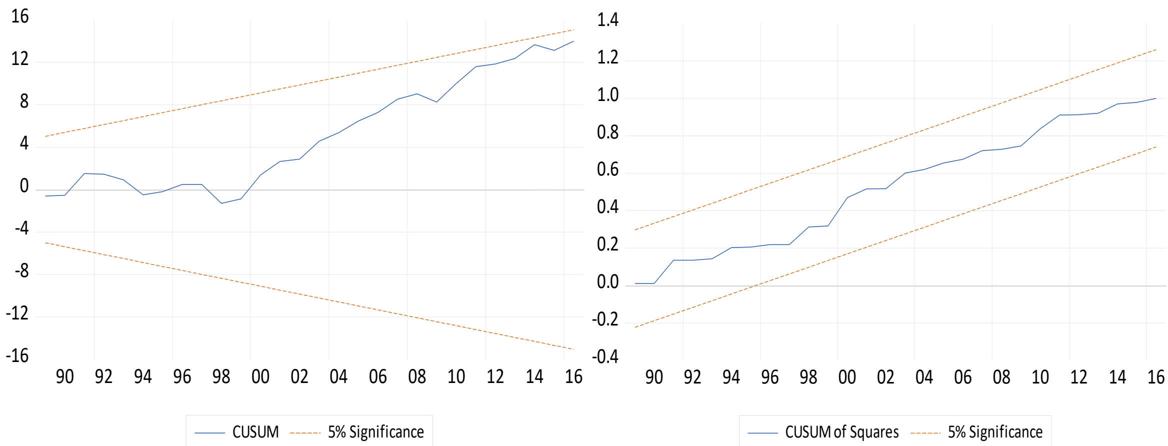


Figure 7: Equation 8- CUSUM and CUSUMSQ for CO2

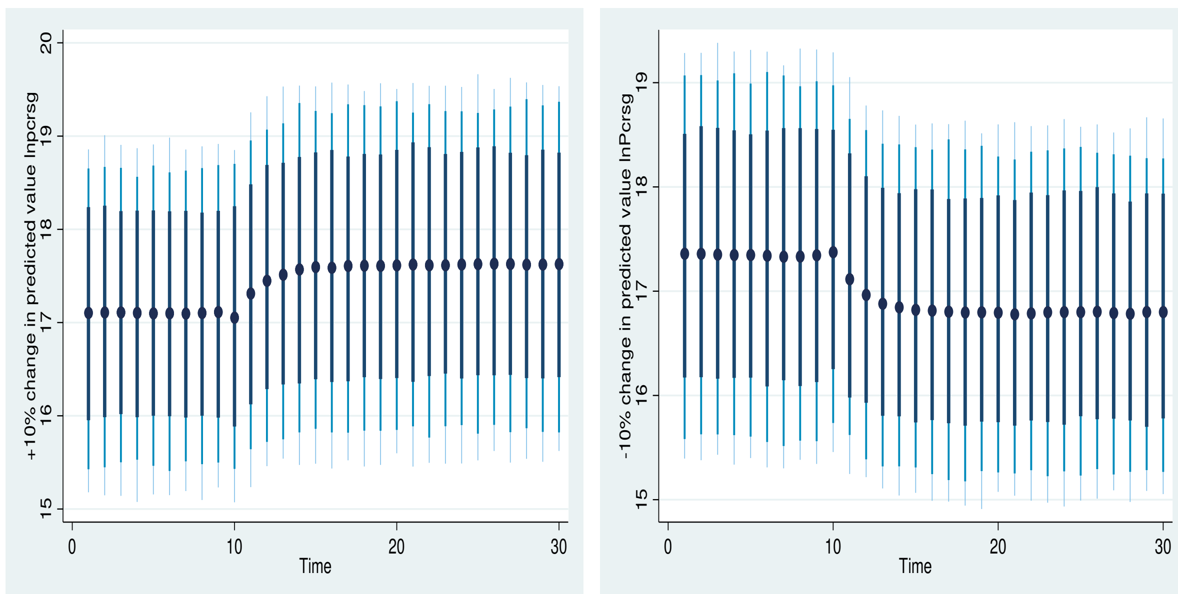


Figure 8 positive or negative 10% innovation in predicted lnPcrsg on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

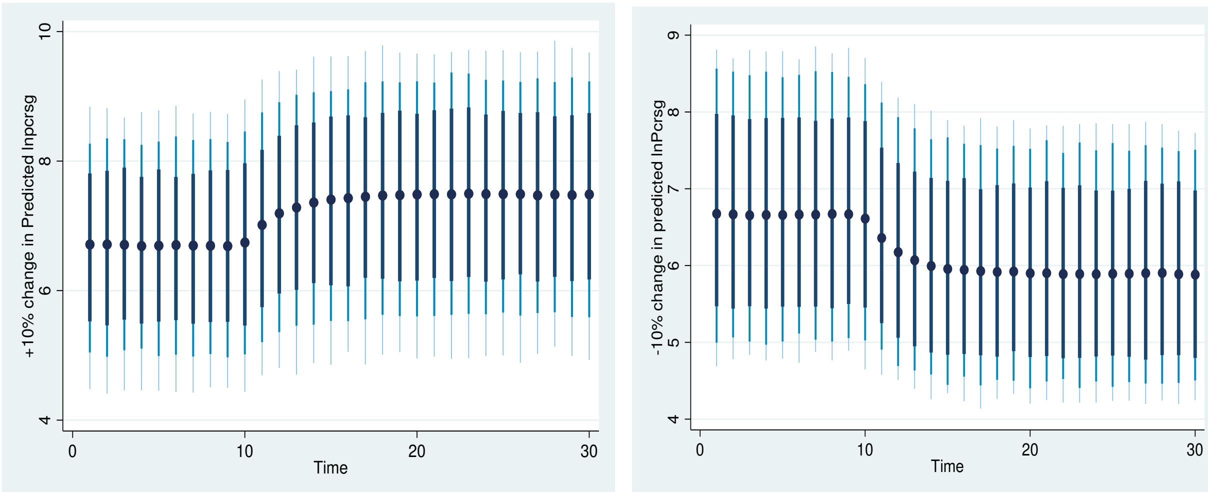


Figure 9 positive or negative 10% innovation in predicted lnPcrsg on lnCEI. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

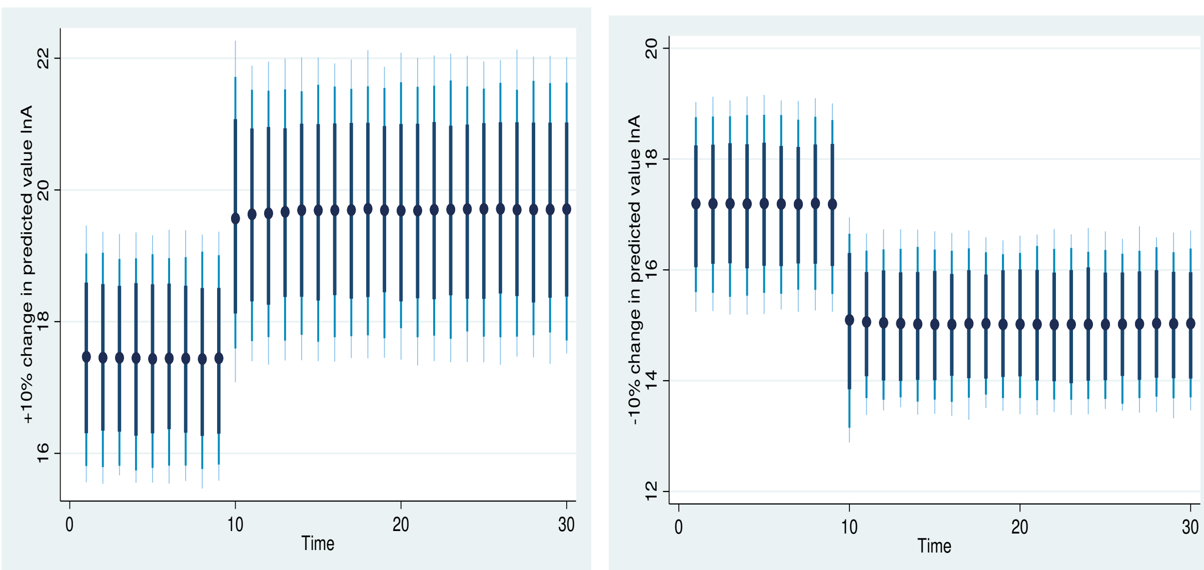


Figure 10: positive or negative 10% innovation in predicted lnA on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

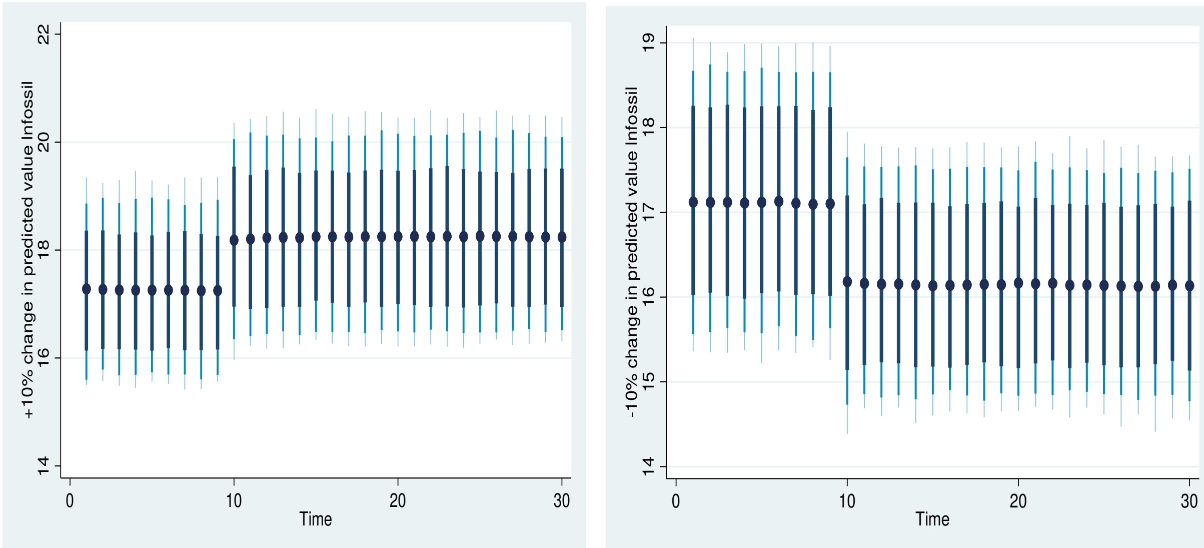


Fig. 11 positive or negative 10% innovation in predicted lnFossil on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

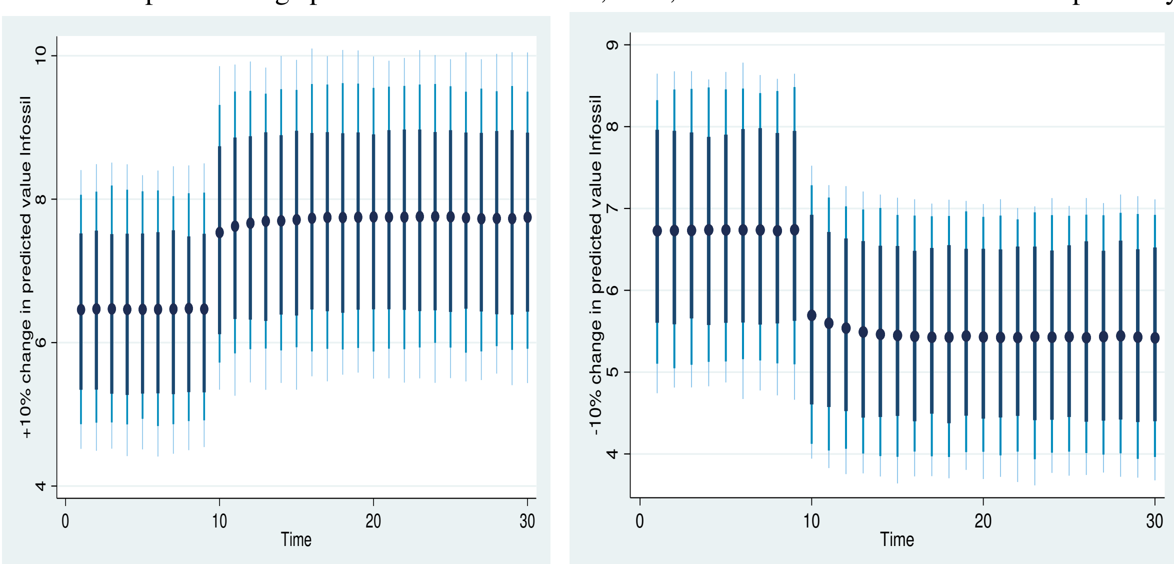


Fig. 12 positive or negative 10% innovation in predicted lnFossil on lnCEI. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

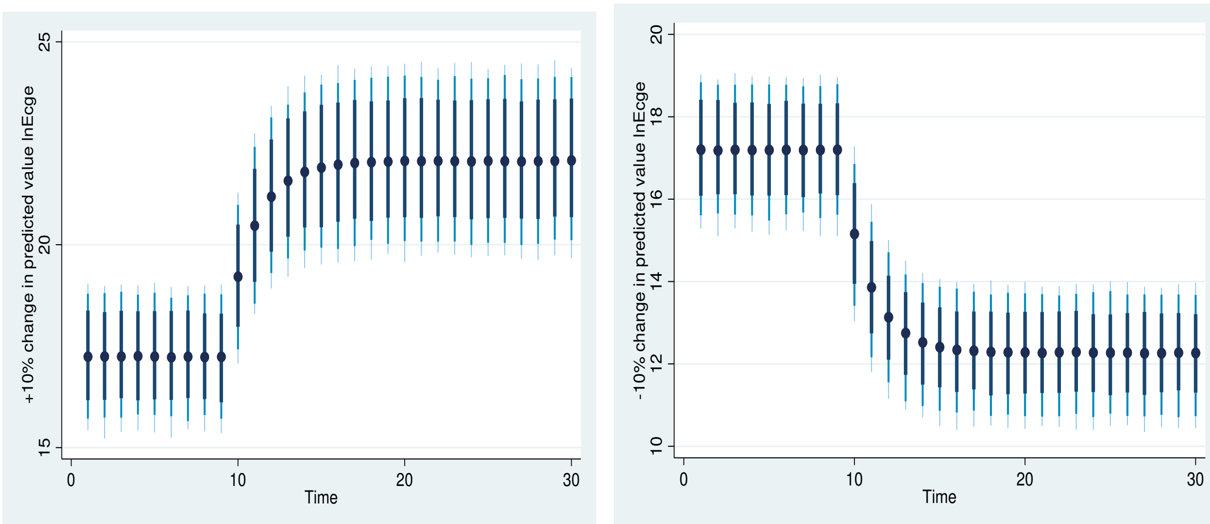


Figure 13: positive or negative 10% innovation in predicted lnEcge on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

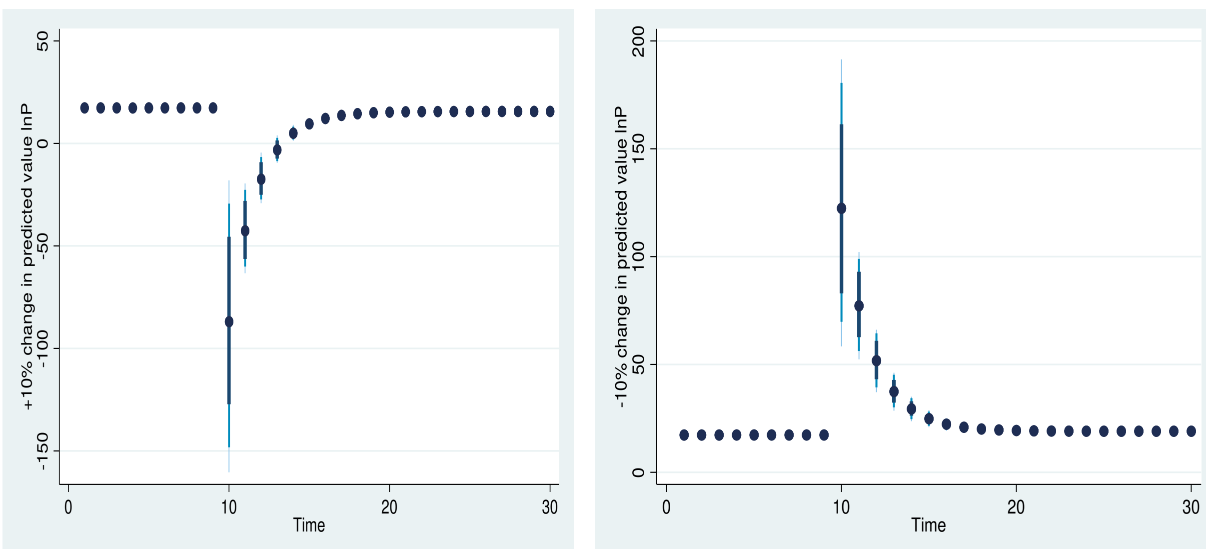
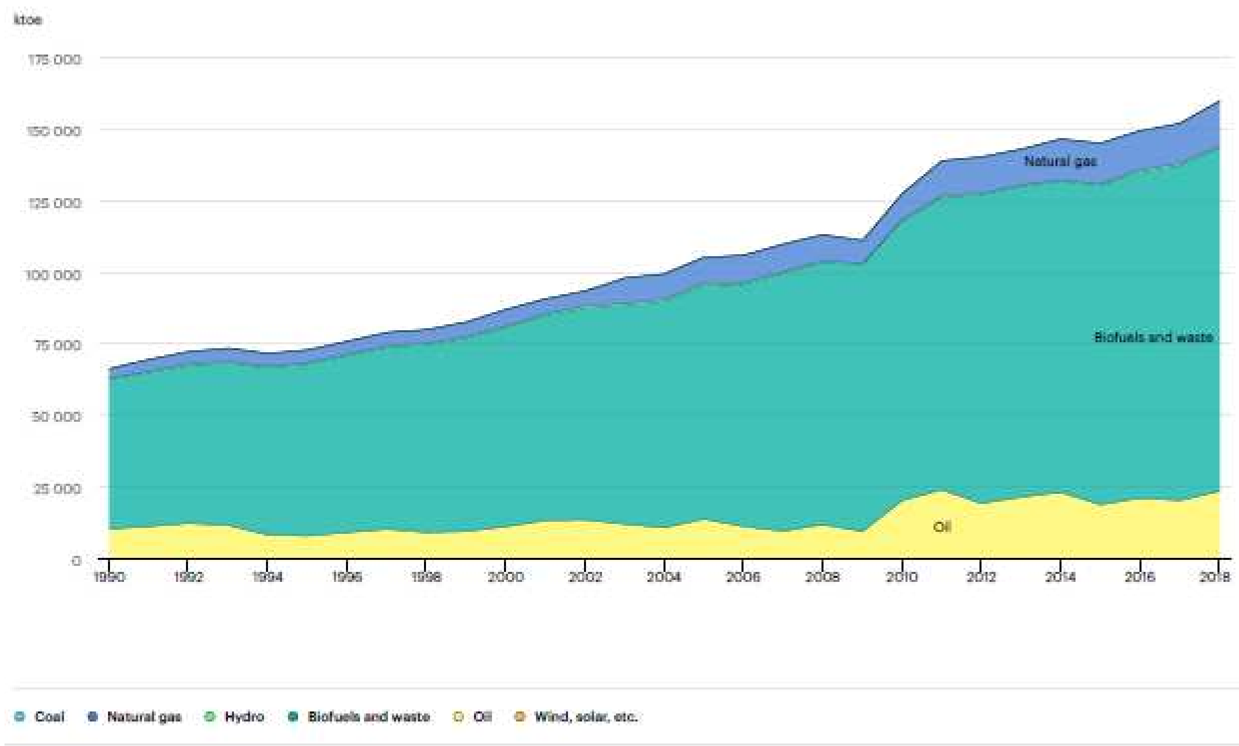


Figure 14: positive or negative 10% innovation in predicted (lnP) on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

Appendix 1

Appendix 2: Total energy supply (TES) by source, Nigeria 1990-2018



Source: IEA World Energy Balances 2020

Declarations

Ethics approval and consent to participate

Note applicable

Consent for publication

Note applicable

Availability of data and materials

Note applicable

Competing interests

On behalf of all authors, the corresponding author states that there is no conflict of interest

Note applicable

Funding

Note applicable

Availability of data and material

Yes

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Figures

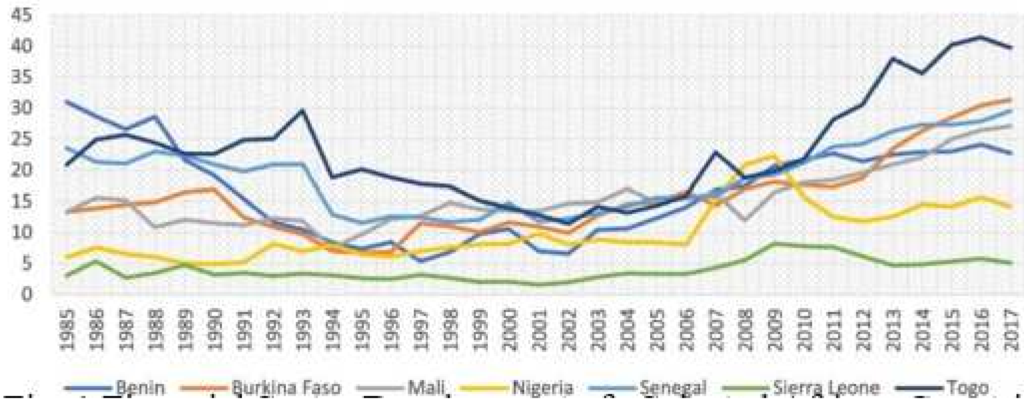

Figure 1

Financial Sector Development of Selected African Countries Source: WDI (2019)

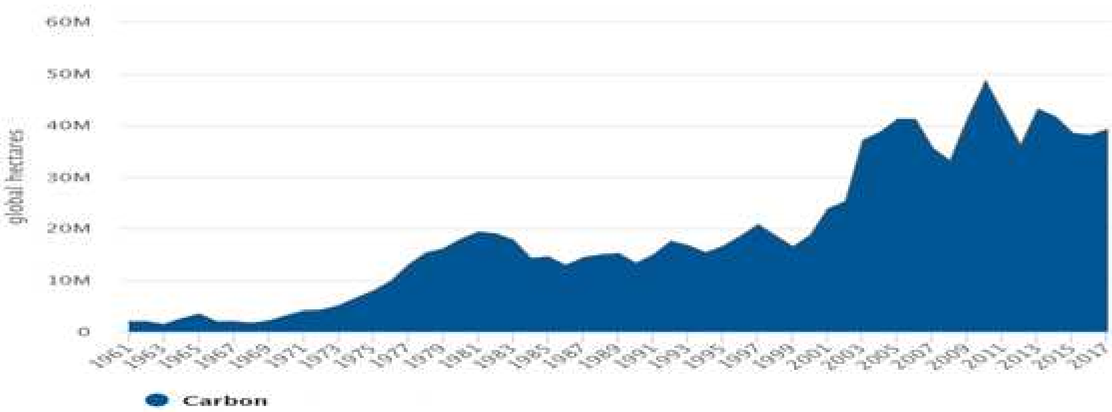

Figure 2

Global Footprint Network 2021 Data source: Global Footprint Network 2021

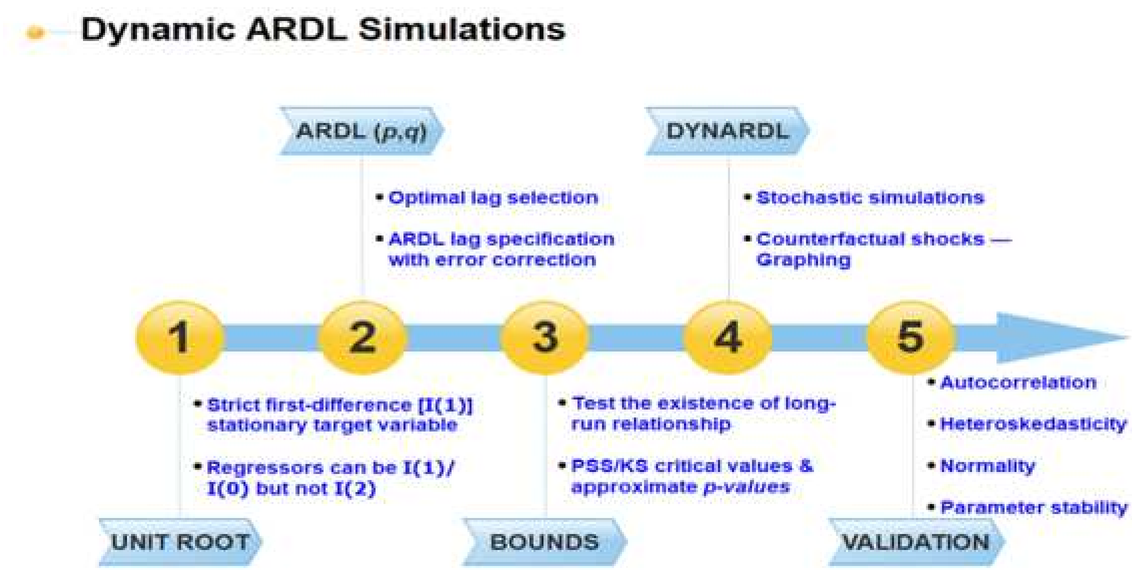

Figure 3

Econometric steps in the application of Dynamic ARDL Simulation Sources: Sarkodie and Owusu (2020)

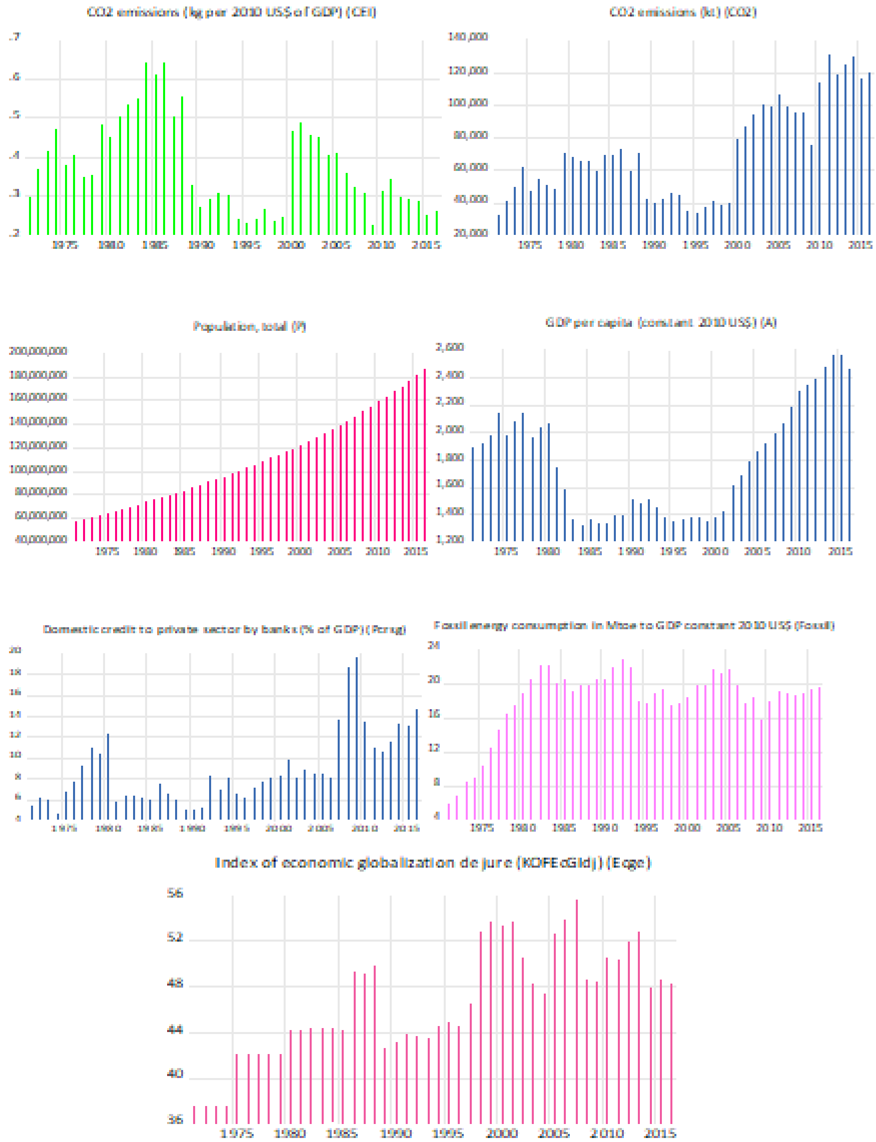

Figure 4

Line plot of the variables from 1971 to 2016. Sources see in Table 2 above

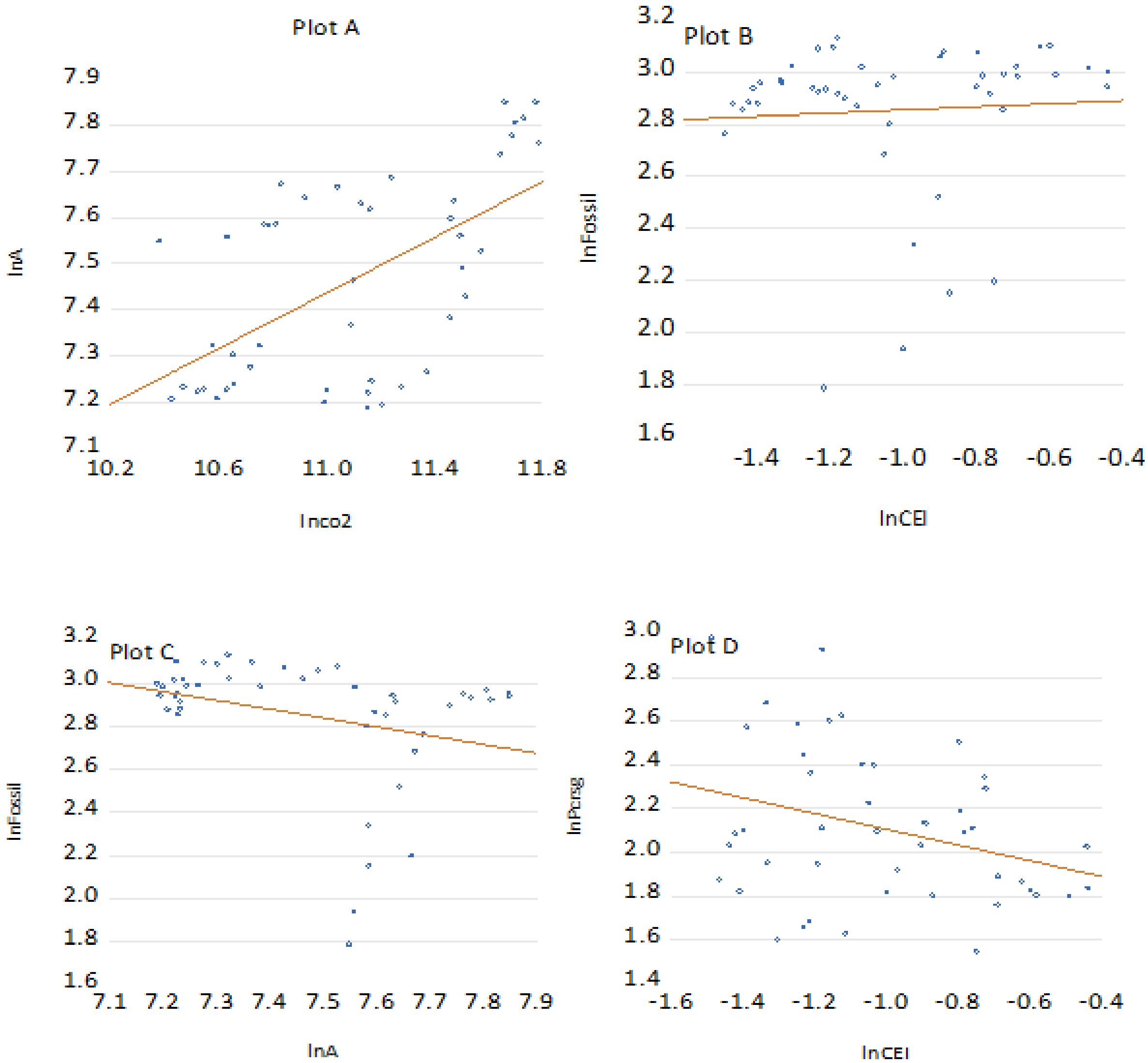

Figure 5

Scatter plots showing the partial correlations of the variables the study

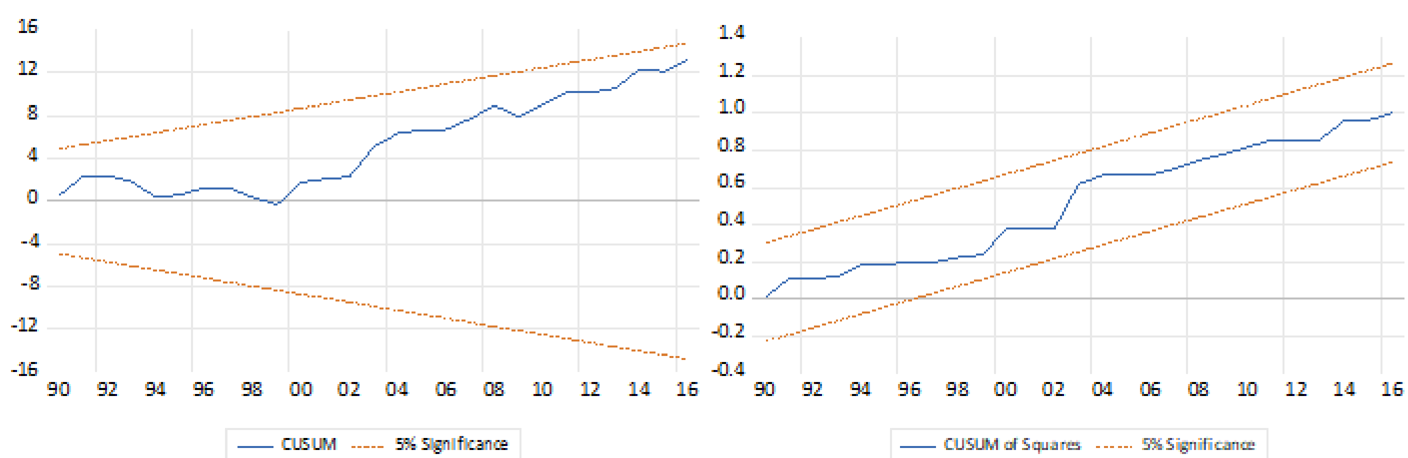

Figure 6

Equation 7 - CUSUM and CUSUMSQ for CO2

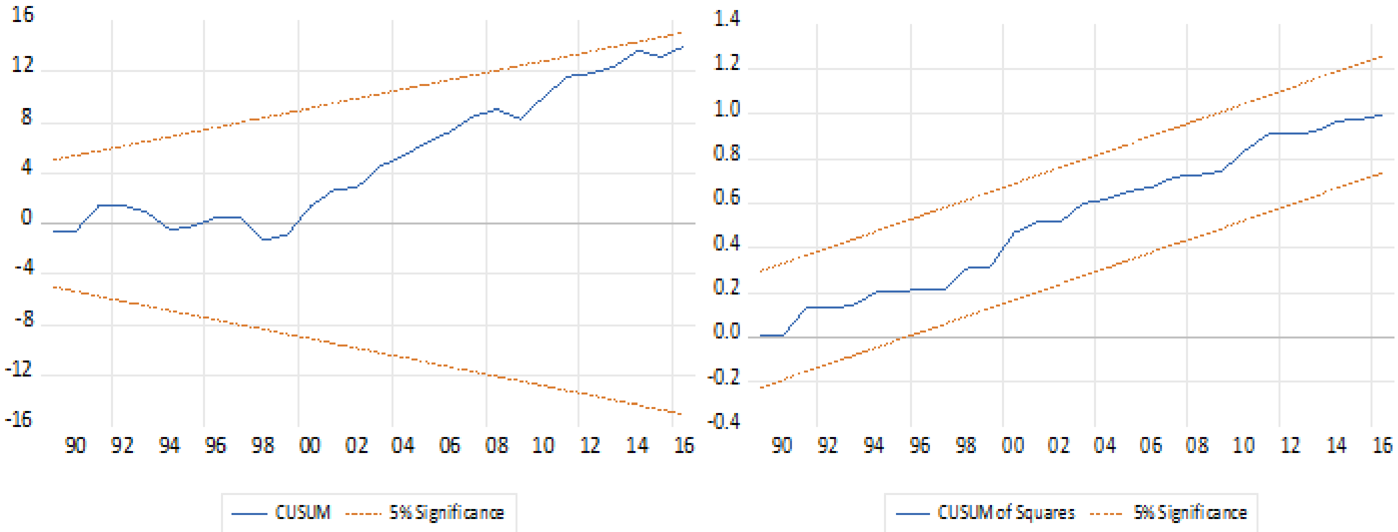

Figure 7

Equation 8- CUSUM and CUSUMSQ for CO2

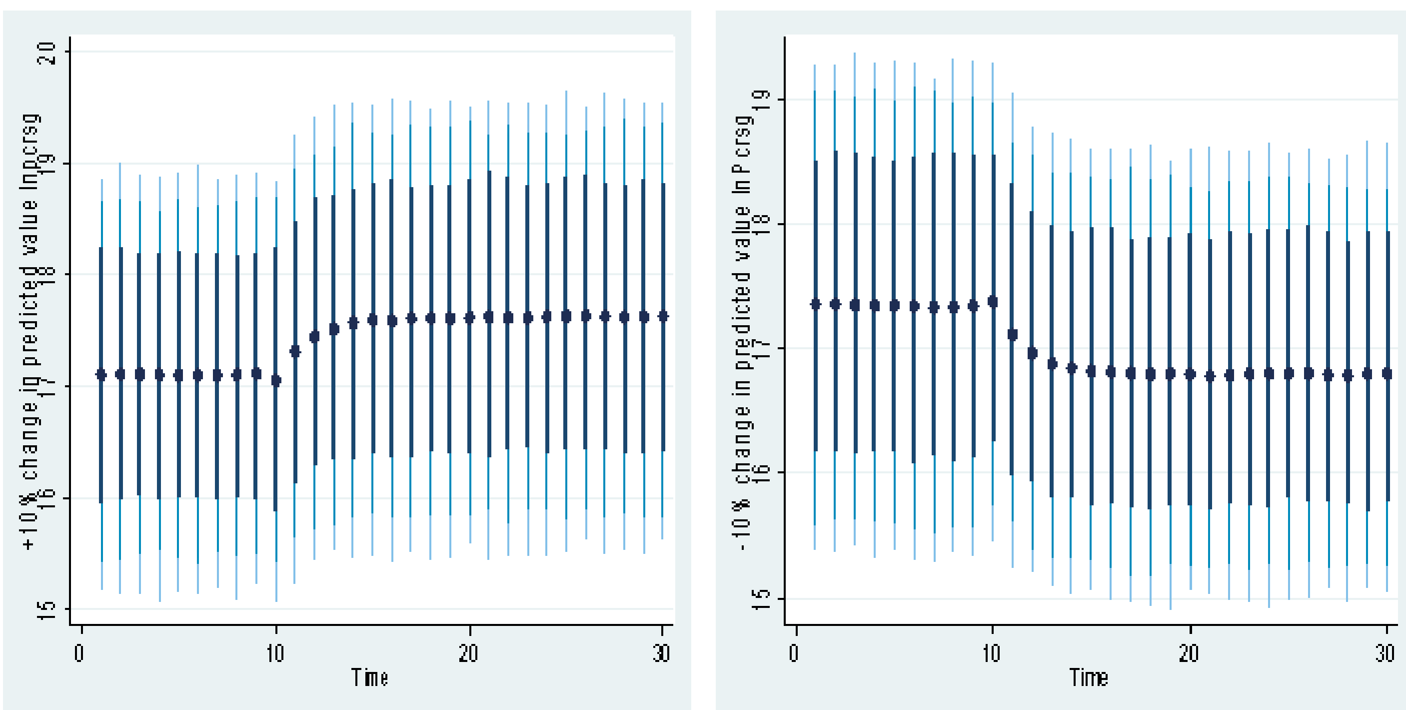

Figure 8

positive or negative 10% innovation in predicted lnPcrsg on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

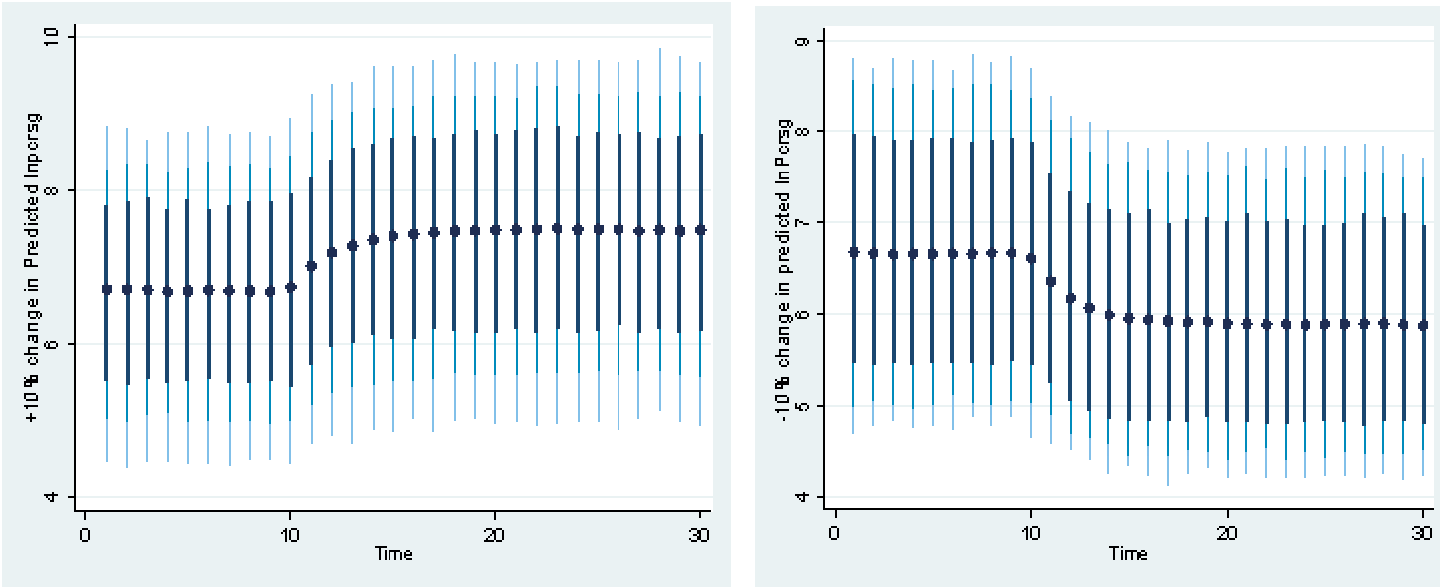

Figure 9

positive or negative 10% innovation in predicted lnPcrsg on lnCEI. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

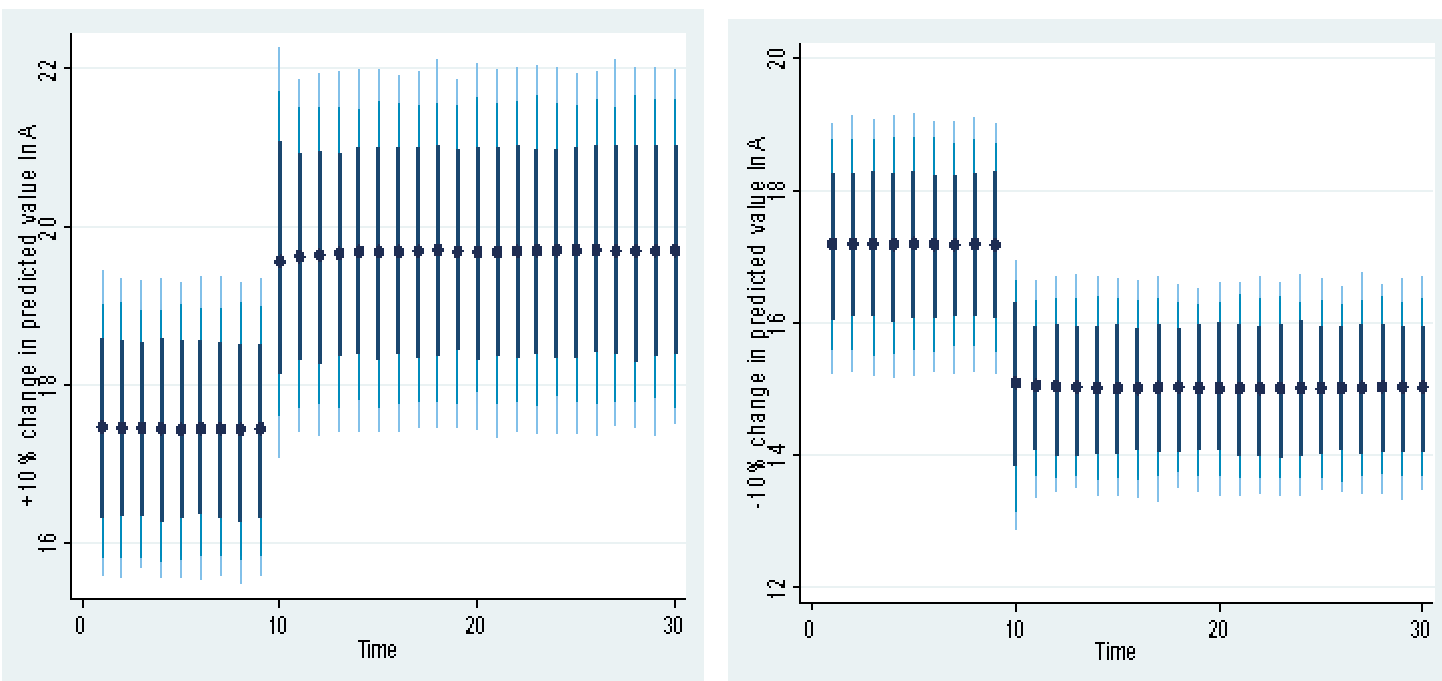

Figure 10

positive or negative 10% innovation in predicted lnA on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

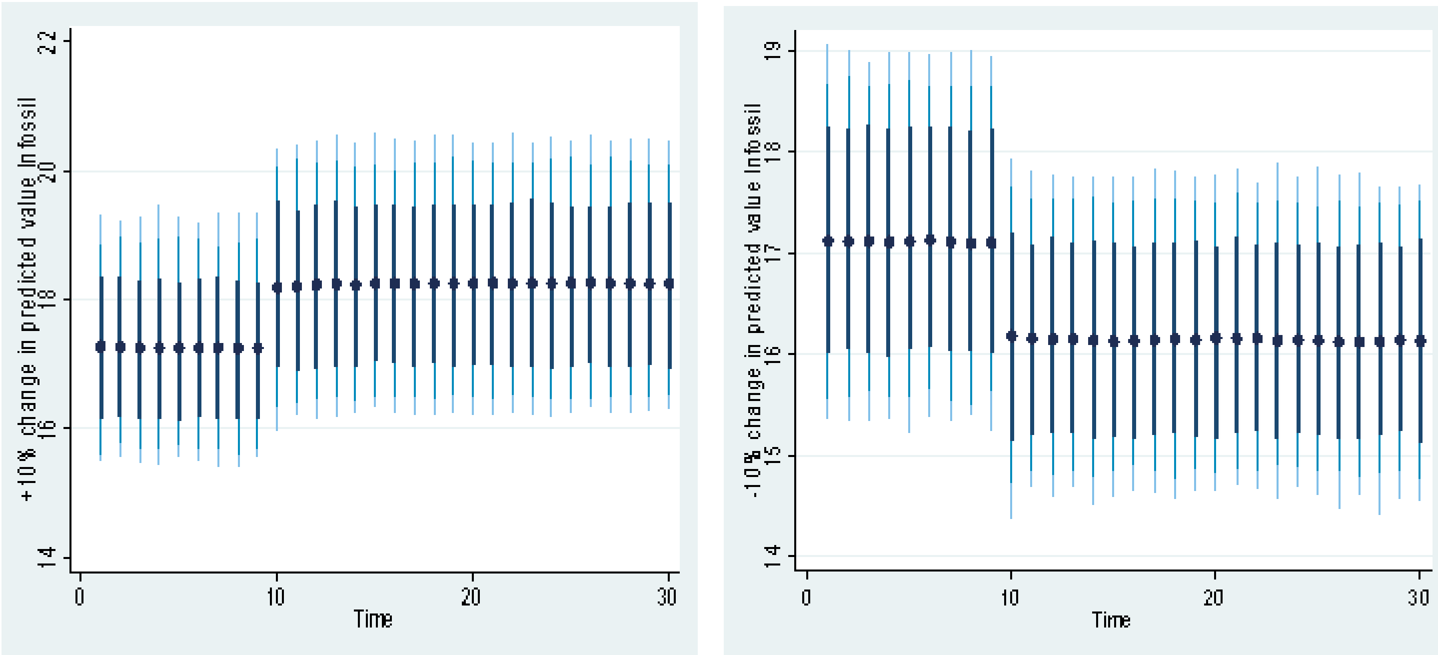

Figure 11

positive or negative 10% innovation in predicted lnFossil on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

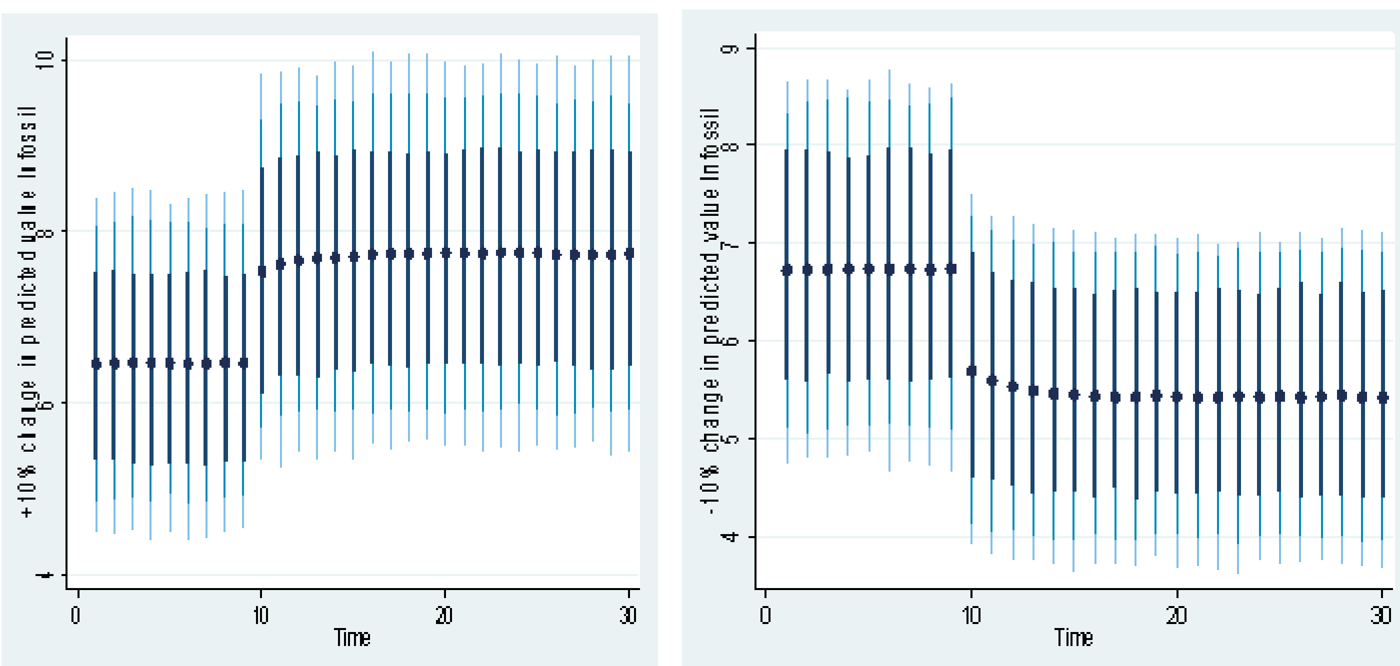

Figure 12

positive or negative 10% innovation in predicted lnFossil on lnCEI. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

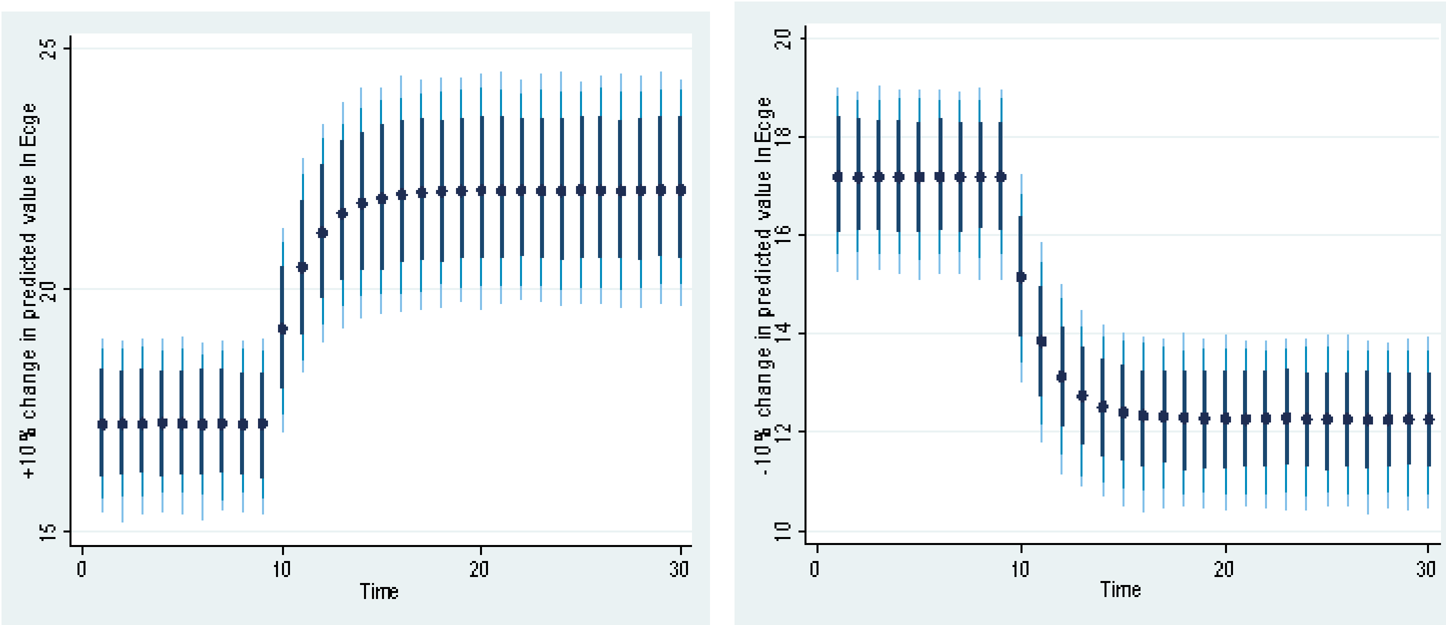

Figure 13

positive or negative 10% innovation in predicted lnEcge on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively

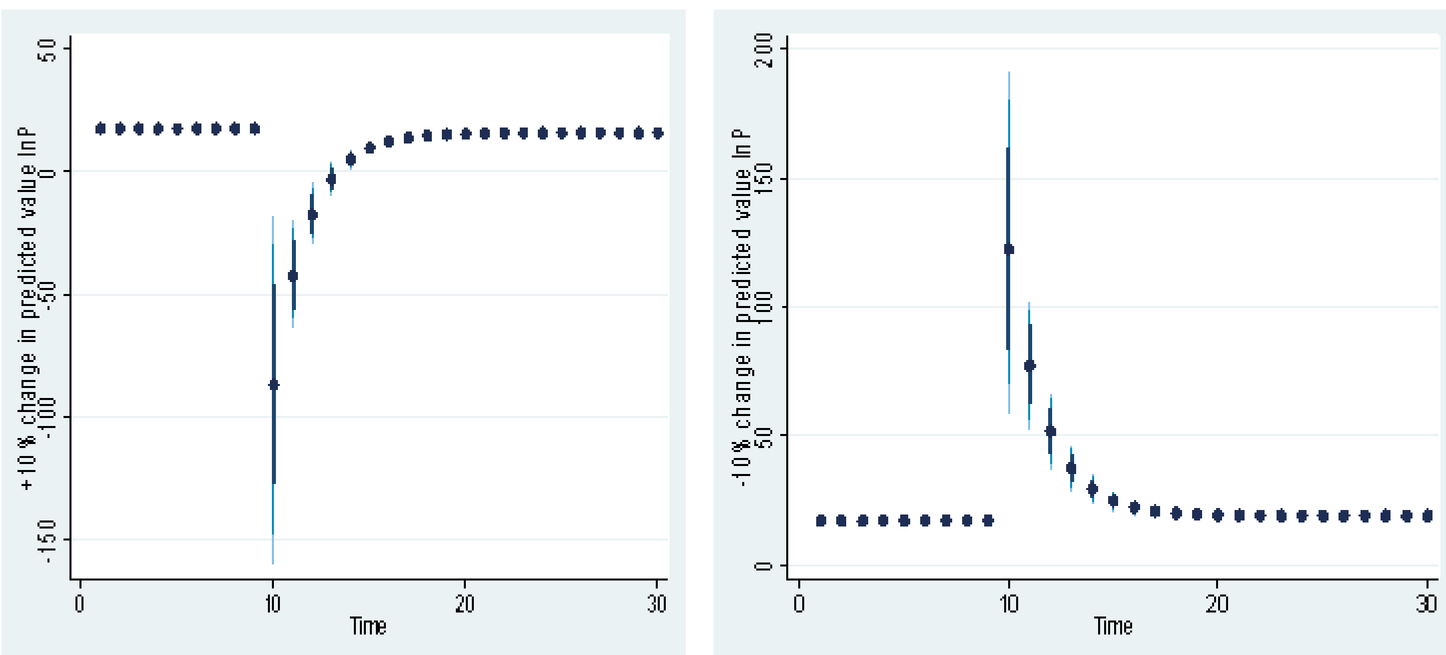

Figure 14

positive or negative 10% innovation in predicted (lnP) on lnCO2. The dots and dark blue to light blue lines explain average predicted value and 75%, 90%, and 95% confidence intervals respectively