Revisiting external financing and environmental sustainability nexus: The role of quality institution

Alih Yusuf

Department of Economics, Prince Abubakar Audu University, Anyigba, Nigeria.
Email: alih91175@gmail.com

Abstract

This study revisits external financing, institutional quality, and environmental sustainability in Nigeria from 1990 to 2024. The study employed autoregressive distributive lag bounds approaches to unravel complex external financing-environmental dynamics. The findings reveal that external financing significantly increases CO_2 emissions and natural resource depletion, with institutional quality playing a pivotal moderating role. The study validates the Kuznets hypothesis, demonstrating that the environmental impact of financial mechanisms is contingent upon robust governance frameworks. The study concludes that the environmental impact of external financing is not automatic but rather conditional upon the strength of existing institutional mechanisms, challenging simplistic assumptions about financial flows and environmental outcomes. This study provides compelling evidence that external financing inflows to Nigeria have significant environmental consequences, contributing to both increased carbon emissions and accelerated natural resource depletion over the study period. The practical implication is that policymakers must recognize that attracting external financing without corresponding institutional strengthening exacerbates environmental degradation, while international financial institutions should condition such financing on demonstrable improvements in environmental governance. The validation of the Kuznets hypothesis further suggests that economic development financed through external sources can ultimately benefit the environment, but only if accompanied by parallel investments in governance infrastructure that enable effective environmental management.

Contents

Contribution of this paper to the literature
The originality of this study lies in its extended analysis of Nigeria within the timeframe of 1990 to 2024 and its novel demonstration that institutional quality serves as a fundamental moderating mechanism in the external financing–environment nexus, thereby validating the Environmental Kuznets Curve hypothesis within this specific contextual framework.

1. Introduction

In the pursuit of sustainable development, the interaction between external financing and environmental sustainability has garnered significant academic and policy discourse. External financing, through foreign direct investment (FDI), remittances, loans, and development aid, holds the potential to drive economic growth and foster environmental quality (Jamil, Rasheed, & Mukhtar, 2023; Jayasekara, 2023). External finance inflow significantly influences environmental quality due to the utilization of advanced technology that reduces CO_2 emission (Ayamba, Haibo, Abdul-Rahaman, Serwaa, & Osei-Agyemang, 2020; Bodas-Freitas & Corrocher, 2019). However, the extent to which these inflows support or hinder environmental sustainability depends heavily on the quality of institutions governing their allocation and use (Azam, Hunjra, Bouri, Tan, & Al-Faryan, 2021; Har & Sin, 2023; Sun, Meng, Zhang, & Wu, 2025). While robust institutions can channel external financing towards eco-friendly technologies and sustainable practices (Zhang & Yan, 2023; Zhao, Dong, Wang, & Nepal, 2024), weak governance, corruption, and lack of transparency often divert resources from environmentally sound projects, thus, exacerbating degradation in developing countries (Akhbari & Nejati, 2019; Ibrahim & Law, 2016; Kareem et al., 2012). Hence, the effectiveness of external financing depends on several factors, with the quality of institutions being a critical determinant (Hossin, Alemzero, Wang, Kamruzzaman, & Mhlanga, 2023; Sharma, Luthra, Joshi, & Kumar, 2022).

Despite obvious environmental constraints, Nigeria has taken steps to improve environmental sustainability. To enhance environmental preservation, the country has accepted international agreements and implemented national policies and frameworks (Naylor & Ford, 2023; Urama & Ozor, 2017). Developing nations like Nigeria generally exhibit a greater environmental footprint than their developed counterparts (Purohit et al., 2019). The Paris Agreement is one of such commitment, in which Nigeria agreed to reduce carbon emissions and strengthen its resilience to climate change. However, environmental controls have frequently been hampered by institutional deficiencies, regulatory loopholes, and limited resources (Ajibola & Akinbami, 2020; Udemba, 2021). Emphasis should be placed on utilizing external financing to promote environmental quality, as well as ensuring investors' compliance with established environmental norms and regulations (Povitkina & Jagers, 2022; Zhao et al., 2024). Hence, the government could implement and enforce environmental sustainability regulations while developing robust frameworks to safeguard property rights (Sun et al., 2025; Zhao et al., 2024).

Literature have emphasized that Nigeria experiences numerous environmental challenges ranging from oil spills annually due to pipeline vandalism, equipment failure, and inadequate maintenance of oil infrastructure (Aigbedion & Iyayi, 2018; Obi & Agada, 2020; Oshienemen, Dilanthi, & Haigh, 2018). These challenges have an adverse effect on water sources, destroy aquatic ecosystems, and devastate farmlands, directly affecting the livelihoods of local communities (Edegbai & Isah, 2018). In addition, gas flaring (the combustion of natural gas during oil extraction) releases harmful pollutants into the atmosphere, contributing to air pollution and climate change (Ochuodho & Spooner, 2018), thus making gas flaring in Nigeria among the highest in the world, posing grave threats to public health and the environment (Efe & Oladosu, 2017). Part of this could be traced to industrial sector activities that have aided in the destruction of essential forest ecosystems (Okey & Nzeadibe, 2018). For example, certain foreign investors introduced technologies to host countries that have significant environmental impacts (Bekhet, Matar, & Yasmin, 2017; To, Ha, Nguyen, & Vo, 2019). Also, deforestation in Nigeria poses significant environmental challenges, endangering biodiversity and exacerbating climate change by reducing carbon sequestration capacity (Azare, Abdullahi, Adebayo, Dantata, & Duala, 2020; Ogunwale, 2015; Ugbaje & Osode, 2019). With an annual primary forest deforestation rate of 3.7%, the highest globally, the forest loss occurs every year (Ogunjimi, 2024). In 2023, Nigeria lost 81.2 thousand hectares of natural forest, equivalent to 54.6 metric tonnes of CO_2 emissions (Ogunjimi, 2024). Deforestation contributes to 87% of the country's total carbon emissions by diminishing forest cover, which plays a crucial role in pollutant absorption (Azare et al., 2020).

It is well established that external financing in developing nations is targeted towards harmonizing industrialization with sustainable economic development (Sun et al., 2025). Developing countries, particularly Nigeria, have been accumulating significant external finance in recent years (World Bank, 2022). This increase in various sources of external finance gives rise to economic activity that would increase household income, the level of savings, aggregate output, consumption, loans, and industrial activities (Akinlo, 2022). However, this country(ies) continues to grapple with low investment levels, hindering long-term sustainable development (Amoh, Abdul-Mumuni, Penney, Muda, & Ayarna-Gagakuma, 2024; Dinga, Fonchamnyo, & Afumbom, 2025). For instance, the critical role of external financing in facilitating economic growth is acknowledged (Daba Ayana, Demissie, & Sore, 2023; Kemoe & Lartey, 2022; Ojeka et al., 2024), but such growth is not free from environmental cost (Shahbaz, Balsalobre-Lorente, & Sinha, 2019). To this, studies alluded that external financing, such as foreign direct investment and external borrowing is associated with environmental pollution (Adediyan, Chigozie, & Obadoni, 2021; Turan & Yanıkkaya, 2021). Literature alludes that multinational companies (MNCs) mostly invest in the extractive and manufacturing subsectors, thereby making them major contributors to increased greenhouse gas emissions and other pollutants that cause climate change (Brown, 2014; Demena & Afesorgbor, 2020). Also, other scholars, Kibria (2022) and Khan, Khan, Ahmed, and Khan (2022) linked remittances to environmental degradation. Nigeria is the third-largest producer of greenhouse gas (GHG) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in Africa, slightly behind South Africa and Zambia (Akinlo, 2022). This interplay demonstrate that the inflow of external financing continues to correspond with worsening environmental quality contrary to better quality.

From an empirical perspective, it is established that a positive nexus exists between the external financing component of FDI and environmental quality worldwide, especially during early growth stages, thus validating Kuznets' hypothesis (Mahalik, Villanthenkodath, Mallick, & Gupta, 2021; Marques & Caetano, 2020; Opoku & Boachie, 2020). It is evident from pool of empirical studies that external financing is deleterious to environmental

quality. However, other studies Jiang, Zhou, Bai, and Zhou (2018) and Awodumi and Adewuyi (2020), demonstrate that external financing leads to improvement in environmental quality. The above finding is corroborated by Ozioko, Rahman, Mohamad, and Abdulwakil (2023) when institutional quality is enhanced. However, study by Sun et al. (2025) reveals that green finance and institutional quality significantly enhance sustainable development goals, while related studies (Lee & Wang, 2022; Xie, 2024) demonstrate that institutional quality influences financial development and environment quality nexus in South Asia.

The motivation for this study stem from the critical role of effective utilization of external financing in enhancing environmental quality both in emerging and developed countries (Amuah et al., 2024; Usama, Solarin, & Salahuddin, 2020). This nexus can be further facilitated through the moderating role of institutional quality (Sun et al., 2025). This is because most empirical studies failed to account for the moderating role of institutional quality. For instance, literature emphasizes weak institutions in sub-Saharan African countries, which could partly explain the negative impact of external financing on environmental quality (Ibrahim & Law, 2016; Kareem et al., 2012). To correct the above, literature (Entezari, Aslani, Zahedi, & Noorollahi, 2023) emphasized that efficient institutions and effective governance is crucial in attaining sustainable development goals. Thus, we are motivated by this submission and consider the moderating role of institutional quality in the external financing and environmental sustainability nexus.

First, building on existing literature, this study provides further evidence by examining the long- and short-run symmetric link between the two. For this purpose, this study applies a linear Auto-Regressive Distributed Lag Model (ARDL) that can effectively address the heterogeneity issue. This technique can account for time-series variations in the data. Second, compared to previous studies, this study uses two indicators of environmental quality CO_2 emission and natural resource depletion, to confirm the environmental effect of external financing moderated by institutional quality. Thirdly, principal component analysis (PCA) is used to construct the index for external financing comprising foreign direct investment, foreign portfolio investment, external borrowing, remittances, and official development assistance. Based on data availability, the index is constructed from 1990 to 2023, and its value ranges from 0 to 100, with 0 indicating the lowest level of external financing. Following from the above, we evaluate the moderating role of institutional quality in shaping the relationship between external financing and environmental sustainability amidst its economic growth. We hypothesize that institutional quality significantly moderates the relationship between external financing and environmental sustainability, enhancing quality outcomes in the presence of robust institutions and exacerbating deleterious impacts when institutional frameworks are weak.

The remainder of the paper is organized as follows. Section 2 presents the brief literature review; Section 3 presents the data and method; Section 4 presents the results and discussion; Section 5 presents policy implications and conclusion.

2. Brief Literature Review

Starting with conceptualization, World Bank (2003) defines external financing as the influx of capital assets like foreign direct investment, foreign portfolio investment, external loans, official development assistance, and remittances, aimed at promoting productivity, entrepreneurship, and domestic investment. CBN (2016) sees it as the resources a country receives from foreign corporations and economies for investment in both tangible and intangible assets. Ouedraogo, Sorouema, and Zahonogo (2018) characterize external financing as a means to diversify exports, transfer technology, contribute to international trade integration, boost trade volume, generate trade tax revenue, intensify domestic competition, and advance the financial sector. External financing is the movement of funds, encompassing capital goods, technical expertise, and managerial capacity, directed into developing or emerging economies (Sule, Doki, & Akighir, 2024).

On the other hand, environmental sustainability refers to the preservation, maintenance, and rational operation of natural resources in a manner that maintains the integrity of each ecosystem, supports livelihoods, certifies the preservation of biodiversity, and avoids environmental deterioration (Basiago, 1998; Gbenda, 2012). According to Morelli (2011), environmental sustainability can be thought of as a state of equilibrium, resilience, and interconnectedness that enables human communities to satisfy their needs without depleting ecosystems. Environmental sustainability advocates a preparation procedure that permits the human community to "live within the boundaries of the biophysical environment" (Goodland, 1995). Environmental sustainability entails several measures embarked upon to preserve biological biodiversity. There are two major measurements of environmental sustainability, namely CO_2 emissions and the environmental sustainability index. However, CO_2 emissions are cited as the best indicator of environmental sustainability or quality in the literature (Biczyńska, 2015; Zheng & Sheng, 2017). In this study, environmental sustainability is conceptualized as the capacity to reconcile the process of obtaining economic input and output without causing harm to or diminishing biological diversity.

This section focuses on the theoretical underpinning. According to Kuznets (1955) theory, there is an inverted-U-shaped relationship between various toxins and per capita income, meaning that as wealth rises, environmental burden increases until a certain point before declining. By implication, the Environmental Kuznets Curve (EKC) posits an inverted U-shaped relationship between per capita income and environmental degradation, where pollution initially rises with economic development but declines after surpassing a certain income threshold, resulting in improved environmental conditions (Kuznets, 1955). The EKC relationship is traditionally modeled as a quadratic function of the logarithm of income. The theory reveals how a technically stated environmental quality capacity changes when an economy's wealth changes. A significant number of works on the subject, such as Awodumi and Adewuyi (2020), Salisu and Ogbonna (2019), Zulquar Nain, Sailaja Bharatam, and Kamaiah (2017), Dogan and Seker (2016), and Sebri and Ben-Salha (2014) have emerged across different spheres. All of these research findings are consistent in that they all show that environmental quality decreases in the early stages of economic prosperity and then improves in the later stages. The inflow of external financing into developing nations is targeted toward harmonizing industrialization with sustainable economic development (Sun et al., 2025).

Economic growth is argued to facilitate environmental improvements over time (Dasgupta, Laplante, Wang, & Wheeler, 2002). The idea gained prominence with the 1987 publication of Our Common Future by the World Commission on Environment and Development, which highlighted the potential to achieve sustainability without disrupting economic progress, a concept described as "having our cake and eating it" (Rees, 1990). On the other hand, growing concerns about the environment, such as climate change, highlight the need to upgrade the institutional

framework. This includes strengthening the country's governance structures, including the rule of law, property rights protection, control of corruption, regulatory quality, and government effectiveness (Kaufmann, Kraay, & Mastruzzi, 2010; Polat, 2020). Although institutional quality is a less considered factor in terms of the causes of environmental degradation (Ibrahim & Law, 2016; Lau, Choong, & Eng, 2014). However, environmental quality improves when government institutions are effective enough to enforce environmental standards and regulations that have been adopted (Yandle, Bhattarai, & Vijayaraghavan, 2019). Countries with strong institutions are perceived as more attractive investment destinations, leading to higher levels of foreign direct investment (FDI) and portfolio inflows (Kemoe & Lartey, 2022; Ojeka et al., 2024), thus facilitating sustainable development.

This section examines empirical literature on the nexus between external financing and environmental sustainability. Starting with Pao and Tsai (2011), who used panel co-integration and causality analyses for BRIC countries, results indicate that FDI has a positive effect on environmental pollution, validating the EKC hypothesis for the BRICs. In a study conducted in Nigeria by Kareem et al. (2012) using Logit regression and finding revealed that *FDI* exhibits a positive effect and a substantial correlation with oil spillage, land degradation, and air pollution. Using fractional cointegration on annual data from 1970 to 2011, the results disclose that early stages of development, weak institutions and unrestricted trade openness increase the extent of environmental degradation due to environmental dumping.

In a sample of 54 countries and for three regional sub-panels; Europe and North Asia, Latin America and the Caribbean, the Middle East, North Africa, and sub-Sahara, Omri, Nguyen, and Rault (2014) using data from 1990 to 2011, showed a bidirectional causality between *FDI* inflows and CO_2 emissions for all the panels, except for Europe and North Asia. Seker, Ertugrul, and Cetin (2015) adopted *ARDL* bounds and causality tests in a study conducted in Turkey, their results showed that *FDI* exhibit a positive but relatively small effect on CO_2 emissions in the long run, while the effects of GDP and energy consumption on CO_2 emissions are quite significant. Similarly, the study of Yang, Jahanger, and Ali (2021) between 1990 and 2016 found that remittances worsened environmental quality. Also, Dash, Gupta, and Singh (2024) using non-linear multivariate panel ARDL (NARDL) model revealed that positive remittance shocks impact environmental degradation, and adverse shocks have a favorable effect. However, the study of Arogundade, Hassan, and Bila (2022) on 22 African countries, using fixed-effect model, and fixed effect instrumental variable regression as well as panel quantile regression, found that remittances enhanced environmental quality. This is corroborated by the finding of Usama et al. (2020), who utilized an ARDL model on annual data from 1981 to 2015 in Ethiopia.

Zheng and Sheng (2017) studied the impact of FDI on China's CO_2 emissions from 1997 to 2009 using OLS, their study revealed that FDI influences the growth of emissions. Similarly, Liu, Hao, and Gao (2017) used panel data from 112 Chinese cities covering the years 2002–2015, employing OLS and fixed-effects (FE) analysis. Their results disclosed differences in the environmental effects of fixed-asset investment (FAI) and FDI. The direct effects of FAI on CO_2 emissions were positive and significant, outweighing the negative indirect effects. Conversely, the direct, indirect, and total effects of FDI on pollutant emissions were all negative. Abdouli and Hammami (2017) used time-series data for 17 MENA nations from 1990 to 2012, and their results from a vector autoregressive (VAR) model demonstrated bidirectional causality between FDI stocks and CO_2 emissions.

Ominyi and Adayi (2017) adopted the OLS technique in a study conducted in Nigeria from 1986 to 2015. Their results showed that FDI contributes to CO_2 emissions, leading to environmental degradation, with the extraction industries as a major source of pollution in Nigeria. Similarly, Jiang et al. (2018) conducted a study using a city-level dataset of 150 Chinese cities in 2014, employing OLS regression, while Hao, Guo, Guo, Wu, and Ren (2020) analyzed data from 29 Chinese provinces from 2003 to 2016 using the three-stage least squares (3SLS) method. Both studies found that China's FDI has increased environmental pollution. In the same vein, Dhrifi, Jaziri, and Alnahdi (2020) conducted a study in 98 developing nations from 1995 to 2017 using 3SLS, revealing a bidirectional causal nexus between FDI, CO_2 emissions, and poverty. However, their findings also indicated a unidirectional causal correlation from FDI to CO_2 emissions. Bediako, Twerefou, and Codjoe (2022) employed a random/fixed effects model and found that FDI inflows into West Africa harm its natural environment. Corroborating these findings, Jinapor, Abor, and Graham (2024) used the Driscoll and Kraay standard error estimation technique on a panel of 45 SSA countries from 2000 to 2019 and reported similar results.

The study by Ali et al. (2019) employed dynamic panel GMM estimations across 47 developing countries, revealing that institutional quality lowers carbon dioxide emissions, which in turn reduces environmental deterioration. In a related study, Egbetoku et al. (2019) applied the ARDL technique to Nigeria, and their results disclosed the presence of an Environmental Kuznets Curve (EKC) for CO_2. Similarly, Opoku and Boachie (2020) also conducted a cross-country analysis of 36 selected African countries from 1980 to 2014, using the pooled mean group method. Their findings indicated that FDI has a large and significant relationship with environmental quality. In the study conducted by Mahmood, Alkhateeb, and Furqan (2020) covering the period 1990–2014 and employing fixed and random effects models, their results demonstrated that FDI affects CO_2 emissions in all countries. This implies that at the early stage of development, developing countries experience poor environmental quality. Awodumi and Adewuyi (2020) conducted a study in the Economic Community of West African States using data from 1980 to 2016. The results of the ARDL model for individual countries, along with random and fixed effects and seemingly unrelated regressions, disclosed that FDI inflows inversely affect environmental efficiency, except in Sierra Leone, where the effect was observed only in the short run.

Mahalik et al. (2021) conducted a study in India from 1978 to 2014 using the ARDL bounds test. Their findings showed that while foreign energy aid inflows, economic growth, FDI, and RMT inflows increase CO_2 emissions, foreign assistance inflows, globalization, and energy consumption significantly reduce CO_2 emissions. Marques and Caetano (2020) analyzed 27 high- and middle-income countries using time-series data from 2001 to 2017, applying a panel ARDL model. Their results showed that while FDI increases emissions temporarily in middle-income nations, it reduces emissions over the long term in high-income countries. Similarly, Iheanachor and Ozegbe (2021) conducted a study in the Nigerian and Ghanaian economies from 2000 to 2008 using OLS. Their findings indicated that by lowering CO_2 emissions, FDI improves environmental sustainability in both countries.

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This section provides brief stylized facts on external financing, institutional quality and environmental quality. Figure 1 illustrates the trends of CO2 emissions (CO2), external financing index (EXF) and institutional quality index (IQI), for Nigeria from 1990 to 2024. Carbon dioxide emissions (CO2) show a distinct downward trend within the study period, peaking at 0.92 metric tons per capita in 1992 before gradually declining to 0.53 metric tons by 2024, representing a 42% reduction despite some fluctuations in the 1990s. External financing (EXF) demonstrates a significant structural shift, starting with consistently negative values (indicating low external financing reliance) until 2004, then transitioning to predominantly positive values from 2005 onward, with notable peaks in 2012 (1.55) and projected increases through 2024, suggesting growing dependence on external financing. The Institutional Quality Index (IQI) shows remarkable improvement, rising from its lowest point (-1.73) in 1990 to positive territory by 2006, peaking at 1.35 in 2010, before experiencing moderate fluctuations and a slight decline in recent years.
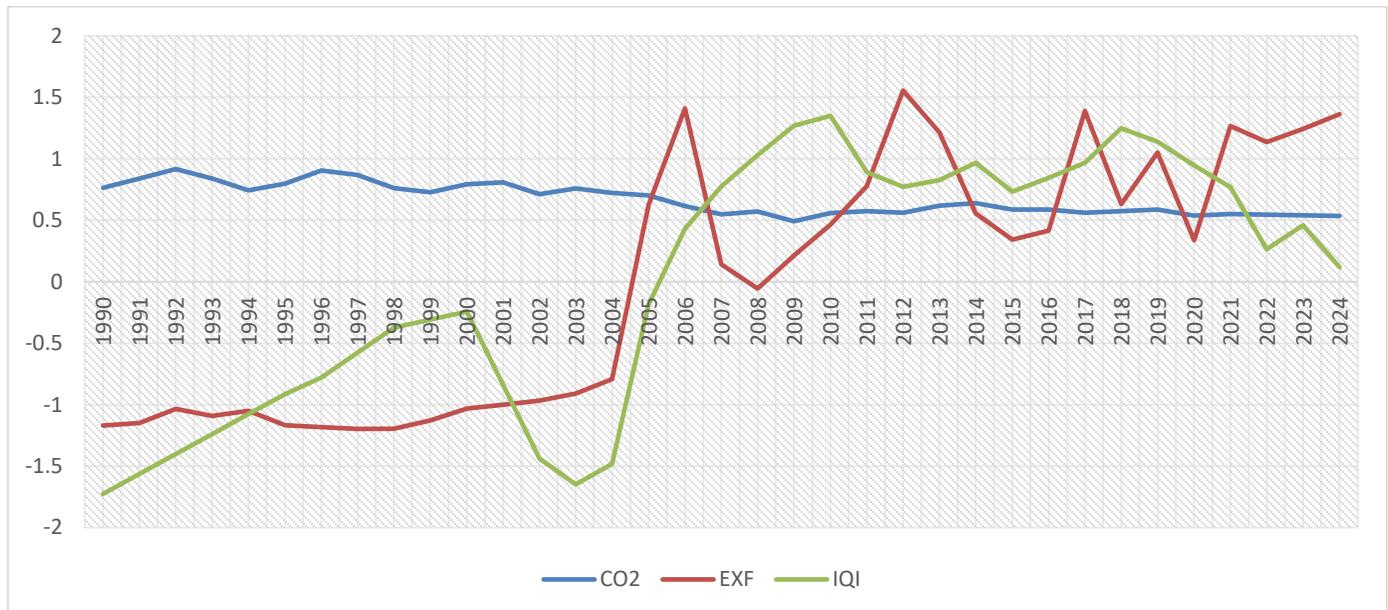

Figure 1. Trends in Carbon dioxide Emission (CO2), External Financing (foreign direct investment, external borrowing, foreign portfolio investment, official development assistance & personal remittance) (EXF) and institutional quality Index (IQI) from 1990 to 2024.

3. Methodology

Considering Nigeria's position in global environmental performance, it is essential to investigate possible best practices worldwide to achieve environmental sustainability. We utilized Nigeria's data from 1990 to 2024 for this study, focusing on relevant trends and strategies. Relevant instruments (institutional quality, foreign direct investment, external borrowing, foreign portfolio investment, official development assistance, personal remittance, official exchange rate, & carbon dioxide emission) and methodology (Auto-regressive Distributive Lag Model (Mahalik et al., 2021; Okpara, 2012; Saeed, 2023; Seker et al., 2015) are adopted to scientifically test environmental sustainability of Nigeria. Other econometric diagnostic techniques include the Heteroskedasticity Test and the Breusch-Godfrey Serial Correlation LM Test: Breusch-Pagan-Godfrey, and Ramsey. RESET Tests. The analysis began with a summary of descriptive statistics and the preliminary Augmented Dickey-Fuller and Phillips-Perron unit root tests. Although some of these measures have been previously adopted by several studies, the literature revealed that these studies are mostly focused on developed and developing countries using panel studies. However, a change in environmental quality resulting from changes in the inflow of external financing into Nigeria over the years, making it among the top three recipients, will also affect these measures of environmental sustainability.

In addition, this study further conducted robustness check using natural resources depletion to validate the main result of this study (Alehile, Yakubu, & Ebeh, 2024; Beyene & Kotosz, 2021) in a country-specific study like Nigeria, which is also lacking in most of the literature reviewed. This study took cue from empirical studies (Ifeanyi, Esther, & Subomi, 2024; Jinapor et al., 2024; Ozioko et al., 2023). For the main objective, carbon dioxide emission (CO_2) proxy for environmental sustainability (Albulescu, Tiwari, Yoon, & Kang, 2019; Opoku & Boachie, 2020). The choice of this indicator is because it is the major greenhouse gas (GHG) emitter contributing almost 72% (Bediako et al., 2022; Sanglimsuwan, 2011). The functional form of the model for achieving this objective is expressed in Equation 1.

$$ESI = f(CAP, LAB, \ EXF * IQI, EXR) \qquad (1)$$

Where: CO2 = Carbon Dioxide Emission (metric tons per capita), EXF = External Financing comprising of foreign direct investment net inflows (BoP current US$), foreign portfolio investment net (BoP current US$), external loans stocks, total (DOD, current US$), personal remittance received (current US$), net official development assistance received (current US$), IQI = Institutional Quality (Index) and EXR = Official Exchange Rate (Rate).

3.1. Construction of the Institutional Quality Index (IQI)

This study sources institutional quality data from the Worldwide Governance Indicators (WGI). Institutional quality is measured by six standard WGI measures: control of corruption, political stability, government effectiveness, regulatory quality, rule of law, and voice and accountability. The choice of institutional quality is because it can potentially play a crucial role in promoting environmental sustainability (Sarkodie & Adams, 2018). These measures of institutional quality were converted into an index using principal component analysis (PCA) to prevent the problem of multicollinearity that exists between measures of institutional quality (Jinapor et al., 2024; Kurul, 2017; Ozioko et al., 2023; Sabir, Rafique, & Abbas, 2019). Based on data availability, the index is constructed from 1990 to 2024, and its value ranges from 0 to 100, indicating the lowest level of institutional quality at 0. According to the ARDL approach proposed by (Pesaran, Shin, & Smith, 2001), which has more merits over

traditionally devised bivariate (Engle & Granger, 1987) and multivariate (Johansen, 1988) cointegration techniques. Equation 2 shows an expanded ARDL bounds testing model in line with the description of our variables reported in Equation 1.

$$\Delta CO2_t = \delta_o + \sum_{i=0}^{p} \varphi_1 \Delta CO2_{t-1} + \sum_{i=0}^{q} \varphi_2 \Delta lnCAP_{t-1} + \sum_{i=0}^{q} \varphi_3 \Delta lnLAB_{t-1} + + \sum_{i=0}^{q} \varphi_4 \Delta EXF * IQI_{t-1} +$$
$$\sum_{i=0}^{q} \varphi_5 \Delta lnEXR_{t-1} + \delta_1 CO2_{t-1} + \delta_2 lnCAP_{t-1} + \delta_3 lnLAB_{t-1} + + \delta_4 EXF * IQI_{t-1} + \delta_5 lnEXR_{t-1} + \varepsilon_t \quad (2)$$

Where $\varphi 1 - \varphi 5$ are the short-run parameters; $\delta 1 - \delta 5$ are the long-run parameters; δ_0 and ε are the intercept term and the white noise stochastic term, respectively; λ is the parameter of the error correction mechanism (ECM); ln is the natural logarithm of the variables, and; Δ is the difference operator. A shock to any of the regressors may not result in an immediate long-run effect on CO2, which creates disequilibrium in the system and requires that the short-run adjusts to its long-run equilibrium through the error correction mechanism $(ECMt - 1)$. The ECM_{t-1} is a one lag error correction term that accounts for the speed of adjustment to the long-run equilibrium.

Once the estimated long-run relationship between the variables is confirmed, then one can derive the short-run coefficients, which could be estimated based on the underlying error correction model (ECM) corresponding to our original long-run Equation 3.

$$\Delta CO2_t = \delta_o + \sum_{j=1}^{p} \delta_{1j} \Delta CO2_{t-j} + \sum_{j=1}^{q} \delta_{2j} \Delta lnCAP_{t-j} + \sum_{j=1}^{q} \delta_{3j} \Delta lnLAB_{t-j} + \sum_{j=1}^{q} \delta_{4j} \Delta EXF * IQI_{t-j} +$$
$$\sum_{j=1}^{q} \delta_{5j} \Delta lnEXR_{t-j} + \delta_4 ECM_{t-1} + v_t \quad (3)$$

ΔY_t: First difference of the dependent variable; ECT_{t-1}: Error Correction Term (Lagged one period); $\delta_0, \delta_1 \dots \delta_4$: represents the short-run dynamics; λ: Speed of adjustment coefficient v_t: Error term

4. Results and Discussion

4.1. Descriptive Statistics

The results of descriptive statistics are presented in Table 1. Carbon dioxide emissions (CO2) average 0.67 metric tons per capita with relatively low variation (SD=0.12), suggesting consistently moderate emission levels with slight positive skewness (0.45), indicating occasional higher emission periods. Capital formation (CAP) averages $55,536.74 million with substantial variability (SD=$35,511.84 million), while the labor force (LAB) shows steady growth from 31.9 million to 78.1 million with moderate dispersion. The external financing index (EXF) and institutional quality index (IQI) both center around zero by construction, with IQI showing negative skewness (-0.35), suggesting more instances of poor institutional quality. Most notably, the official exchange rate (EXR) demonstrates extreme variability with a mean of ₦206.55/$ but a maximum of ₦1,540/$, exhibiting severe positive skewness (3.37) and extremely high kurtosis (15.52). The Jarque-Bera statistic (294.69) with a probability of 0 confirms the exchange rate's significant non-normal distribution, reflecting Nigeria's currency instability during the period. Other variables show relatively normal distributions based on their Jarque-Bera probability values exceeding 0.05.

Table 1. Descriptive Statistics.

	CO2	CAP	LAB	EXF	IQI	EXR	NRD
Mean	0.669	55536.74	51,587	0.000	0.000	206.548	6.777
Median	0.619	56153.13	50,107	0.213	0.265	131.274	6.681
Maximum	0.916	145948.4	78,099	1.554	1.349	1540	19.268
Minimum	0.491	12343.17	31,881	-1.197	-1.725	8.038	0.659
Std. Dev.	0.124	35511.84	13,440	1.015	1.014	284.405	4.329
Skewness	0.447	0.696	0.304	0.070	-0.348	3.369	0.699
Kurtosis	1.859	2.599	1.972	1.396	1.639	15.515	3.324
Jarque–Bera	3.062	3.064	2.081	3.779	3.408	294.688	3.008
Probability	0.216	0.216	0.353	0.151	0.181	0	0.222

Table 2. Summary of Conventional Unit Root Test.

Variables	ADF Unit Root				PP Unit Root				Inference
	Level	Prob.	1st Diff.	Prob.	Level	Prob.	1st Diff.	Prob.	
CO2	-1.211	0.658	-5.854a	0.000	-0.944	0.762	-7.266a	0.000	I(1)
CAP	-3.267c	0.089	-4.369 a	0.008	-0.481	0.883	-5.040a	0.000	I(1)
LAB	-1.778	0.692	--5.363 a	0.000	-0.045	0.948	-3.272b	0.025	I(1)
EXF	-1.409	0.566	-5.395 a	0.000	-1.013	0.738	-11.875a	0.000	I(1)
IQI	-2.117	0.239	-3.276b	0.024	-1.829	0.361	-3.286b	0.024	I(1)
EXR	-0.611	0.855	-4.825a	0.000	-0.646	0.847	-4.802a	0.000	I(1)
NRD	-0.776	0.810	-6.458a	0.000	-2.259	0.191	-18.475a	0.000	I(1)

Note: a, b and c indicate statistical significance at 1%, 5% and 10%, respectively. ADF and PP denotes Augmented Dickey Fuller and Phillip Perron.

4.2. Unit Root Test

It is important to ascertain the properties of the series under consideration using conventional unit root tests. Based on this, the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron tests are presented in Table 2. The results in Table 2 reveal that all the series became stationary at first difference [I(1)] at a 5% significance level. This outcome reinforces the choice of the Autoregressive Distributed Lag (ARDL) model as the estimation technique.

Table 3. Summary of ARDL Results.

Panel A	Model without interaction			
	ARDL Bounds Test Result			
Level of Significance	**F-statistic**		**Lower Bound**	**Upper Bound**
10%	9.007		2.08	3.00
5%			2.39	3.38
1%			3.06	4.15
Short-run estimates			**Long-run estimates**		
Variables	*Coef.*	*Prob.*	*Variables*	*Coef.*	*Prob.*
$\Delta \ln CO2_{t-1}$	-0.271^a	0.001			
$\Delta \ln CAP_{t-1}$	-1.418^a	0.001	lnCAP	-0.624^a	0.000
$\Delta \ln LAB_{t-1}$	1.143^a	0.016	lnLAB	0.503^a	0.003
ΔEXF_{t-1}	0.515^a	0.004	EXF	0.227^a	0.001
ΔIQI_{t-1}	-0.054	0.249	IQI	-0.024	0.209
$\Delta \ln EXR_{t-1}$	-0.122^b	0.033	lnEXR	-0.054^a	0.012
ECT_{t-1}	-0.271	0.000			
Panel B	**Model with interaction**				
	ARDL Bounds Test Result				
Level of Significance	**F-statistic**		**Upper Bound**	**Lower Bound**	
10%	8.996		3.03	4.06	
5%			3.47	4.57	
1%			4.40	5.72	
Short-run estimates			**Long-run estimates**		
Variables	*Coef.*	*Prob.*	*Variables*	*Coef.*	*Prob.*
$\Delta \ln CO2_{t-1}$	-0.534^a	0.007			
$\Delta \ln CAP_{t-1}$	-0.097^c	0.096	lnCAP	-0.257^c	0.094
$\Delta \ln LAB_{t-1}$	10.461^b	0.034	lnLAB	14.089^a	0.009
$\Delta EXF*IQI_{t-1}$	0.170^a	0.017	EXF * IQI	0.165^a	0.014
$\Delta \ln EXR_{t-1}$	-0.172^a	0.031	EXR	-0.166^a	0.007
ECT_{t-1}	-0.534^a	0.000			

Note: $^{a, b}$ and ^{c} indicate statistical significance at 1%, 5% and 10%, respectively.

4.3. ARDL Bounds Testing Results and its Discussion

The result in Table 3 is the summary of the ARDL bounds test alongside the short-run and long-run estimates. Panel A shows results without interacting external financing with institutional quality, while Panel B presents model results with external financing and institutional quality interaction. Starting with Panel A, the bounds test with F-Statistic of 9.006642 is higher than both lower and upper bounds critical values of Narayan (2005) at various significance levels. This indicates the existence of long-run relationship between carbon dioxide emission and other determinants in the carbon dioxide emissions model in Nigeria. Specifically, the short-run and long-run estimates for model without interactive term shows that external financing exhibit significant positive effect on environmental sustainability.

This finding conforms to existing literature, where the emphasized on the deleterious effect of foreign direct investment and remittances on CO2 emission (Dash et al., 2024; Kareem et al., 2012; Mahalik et al., 2021; Ominyi & Adayi, 2017; Seker et al., 2015; Yang et al., 2021) but contrary to other studies conducted in China and 22 African countries (Arogundade et al., 2022; Jiang et al., 2018; Usama et al., 2020). This implies that a unit increase in external financing will bring about 0.514unit increase in carbon dioxide emission proxied in both short-run and long-run. Similarly, this outcome in Nigeria is not surprising within the West African countries as earlier findings reveal that external financing, such FDI is very harmful to the natural environment (Bediako et al., 2022; Egbetoku et al., 2019; Jinapor et al., 2024; Opoku & Boachie, 2020).

However, institutional quality exerts insignificant negative effect on CO2 emission, demonstrating weak and inconsequential institutional setup in Nigeria. This corroborates with Kareem et al. (2012) earlier submission that at the early stages of development, weak institutions increase the extent of environmental degradation due to environmental dumping. Although similar study by Ali et al. (2019) emphasized that institutional quality lowers CO2 emission in 47 developing countries. The error correction term of -0.27 significant at 5% level, indicating the rate of adjustment to the long-run horizon for the carbon dioxide emission model without an interactive term.

Moving to Panel B, the bounds test result with F-statistic of 8.996216 is higher than both lower and upper bounds critical values of Narayan (2005) at various significance levels, indicating strong long-run relationship between carbon dioxide emission and other explanatory variables in the model with interactive term. Specifically, the model with interaction on Panel B reveals that external financing-institutional quality (EXF*IQI) exert significant positive effect on CO2 emission in both short-run and long-run. This indicates that a unit increase in EXF*IQI, results in increase of 0.170 unit and 0.164 unit in CO2 emission, respectively, ceteris paribus, thereby causes environmental damage.

This result conforms to earlier empirical findings (Aigbedion & Iyayi, 2018; Obi & Agada, 2020; Ugbaje & Osode, 2019). This further implies that there is existence of weak institutional frameworks in Nigeria to help channel these external financing toward environmentally sustainable initiatives (Ajibola & Akinbami, 2020; Udemba, 2021). The error correction term of -0.53 indicates the rate of adjustment to the long-run horizon is significant for the carbon dioxide emission model with an interactive term.

Table 4. Diagnostic and Pos-Estimation Tests.

Panel A	Model without interaction		
Adj. R²	*Linearity Test*	*Autocorrelation test*	*Heteroscedasticity test*
	Ramsey RESET	**Breusch-Godfrey Test**	**Breusch-Pagan-Godfrey**
0.933	0.392 (0.711)	6.290 (0.058)	0.411 (0.944)
Panel B	*Model with interaction*		
0.932	1.113 (0.328)	3.606 (0.159)	7.333 (0.018)

Note: Probability values for the post-estimation test are in parentheses.

On the adequacy of the models, the null hypothesis of linearity is maintained and the model is appropriately stated as the Linearity RESET test verifies that the model is stable (see Table 4 & 6). The presence of autocorrelation and the rejection of the serial correction null hypothesis, which appears to be consistent with the CO_2 emission models and natural resource depletion models (see Table 4 & 6), were further investigated in this work. Also, this study discovered that the CO_2 emission and natural resource depletion model's null hypothesis of heteroscedasticity was repeatedly rejected (see Table 4 & 6). These indicators obtained confirm the estimated models is efficient and robust for policy inference. The cumulative sum of the recursive residuals shows that the equation is stable within the sample period and the graphs are presented in Figures 2, 3, 4 and 5. The movement of recursive residuals inside the critical lines is suggestive of coefficient stability. This further substantiates the long-run equilibrium relationship between the variables.
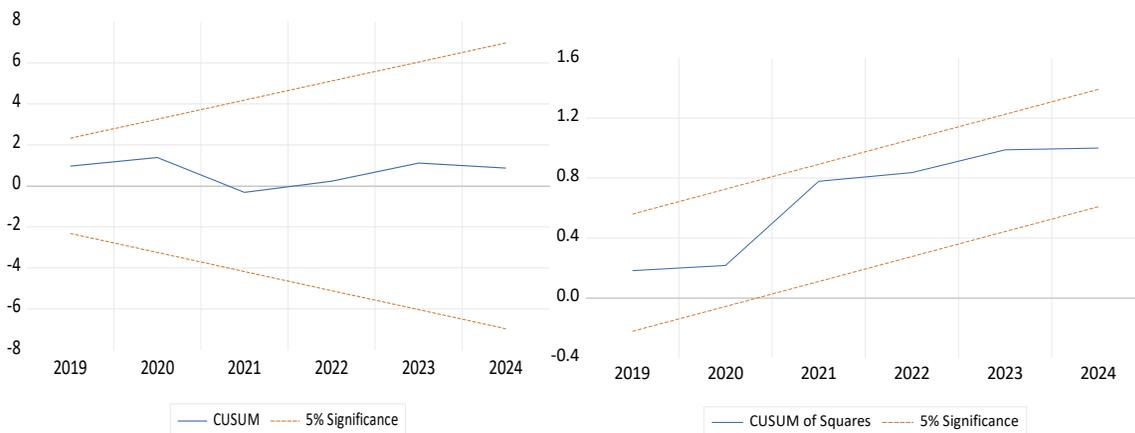

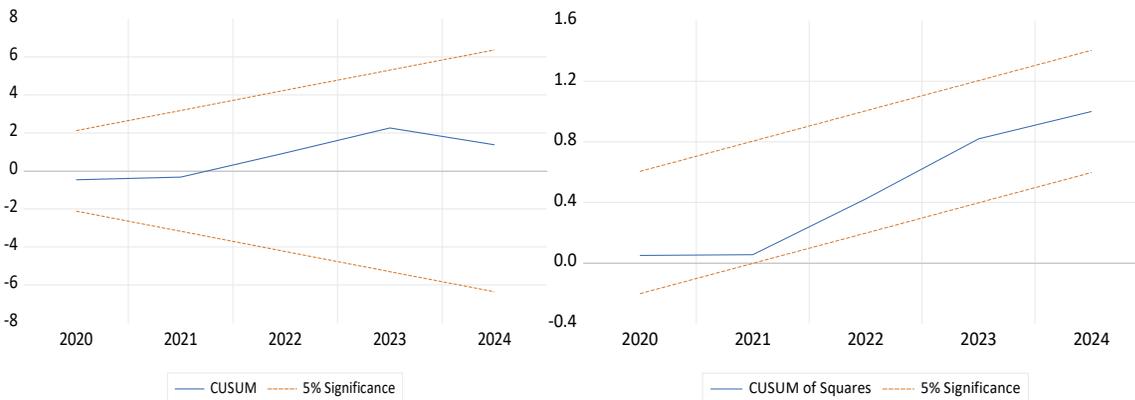**Figure 2.** CUSUM and CUSUM Square for Model without interaction term.

Figure 3. CUSUM and CUSUM Square for Model with interaction term.

4.4. Robustness Check

This further employed the series of natural resource depletion to validate the model of environmental sustainability using carbon dioxide emission. Starting with the ARDL bounds test, the natural resource depletion model demonstrates a long-run relationship amongst the series considered at 5% significance level. Tables 5 reveal that a comparison with the initial results shows that the signs and significance of the coefficients remain predominantly unchanged across all models. Specifically, on the model without the interactive term of institutional quality, external financing exhibits a significant positive effect on environmental sustainability in both the short run and long run at a 5% significance level. Accordingly, a unit change in the series of external financing results in an increase of 2.697 and 1.560 units of CO_2 emissions in the short run and long run, respectively. This implies that these capital inflows have the potential to cause depletion of natural capital associated with resource exploitation. Conversely, the results of the model with the interactive term of institutional quality with external financing exert a positive effect and a significant relationship with CO_2 emissions, corroborating the results of the model without the interactive term. This means that a unit increase in the series of EXF*IQI will lead to a 3.949-unit and 2.921-unit increase in CO_2 emissions in both the short run and long run. The results of both models validate the Kuznets hypothesis in Nigeria (Egbetoku et al., 2019; Ominyi & Adayi, 2017; Opoku & Boachie, 2020). Again, both outcomes demonstrate the inherent capacity of external financing to influence increases in CO_2 emissions in a developing country like Nigeria. The error correction term (ECT) values of -0.728231 and -0.351641 indicate that the rate of adjustment to the long-run horizon is significant for both models.

Table 5. Robustness check results.

Panel A	Model without interaction			
	ARDL Bounds Test Result			
Level of Significance	**F-statistic**		**Lower Bound**	**Upper Bound**
10%	4.584		2.62	3.35
5%			2.62	3.79
1%			3.41	4.68
Short-run estimates			*Long-run estimates*		
Variables	*Coef.*	*Prob.*	*Variables*	*Coef.*	*Prob.*
$\Delta lnNRD_{t-1}$	−0.728[a]	0.000			
$\Delta lnCAP_{t-1}$	17.693[a]	0.005	**lnCAP**	10.238[a]	0.000
$\Delta lnLAB_{t-1}$	−54.161[a]	0.001	**lnLAB**	−31.339[a]	0.000
ΔEXF_{t-1}	2.697[b]	0.023	**EXF**	1.561[a]	0.013
ΔIQI_{t-1}	−3.401[b]	0.045	**IQI**	−1.968[a]	0.016
$\Delta lnEXR_{t-1}$	−1.728[a]	0.000	**lnEXR**	−2.154[b]	0.026
ECT_{t-1}	−0.728[a]	0.000			
Panel B	**Model with interaction**				
	ARDL Bounds Test Result				
Level of Significance	**F-statistic**		**Upper Bound**	**Lower Bound**	
10%	6.036		2.2	3.09	
5%			2.56	3.49	
1%			3.29	4.37	
Short-run estimates			*Long-run estimates*		
Variables	*Coef.*	*Prob.*	*Variables*	*Coef.*	*Prob.*
$\Delta lnNRD_{t-1}$	−0.752[a]	0.000			
$\Delta lnCAP_{t-1}$	14.817[a]	0.001	lnCAP	10.962[a]	0.000
$\Delta lnLAB_{t-1}$	−58.299[a]	0.000	lnLAB	−43.132[a]	0.000
$\Delta EXF*IQI_{t-1}$	3.949[a]	0.003	EXF ∗ IQI	2.922[a]	0.005
$\Delta lnEXR_{t-1}$	0.527	0.661	EXR	0.389	0.667
ECT_{t-1}	−0.752[a]	0.000			

Note: [a], [b] and [c] indicate statistical significance at 1%, 5% and 10%, respectively.

Table 6. Diagnostic and Pos-Estimation Tests.

Panel A	Model without interaction		
Adj. R²	**Linearity Test**	**Autocorrelation test**	**Heteroscedasticity test**
	Ramsey RESET	**Breusch-Godfrey Test**	**Breusch–Pagan-Godfrey**
0.754	2.039 (0.062)	1.814 (0.205)	0.929 (0.563)
Panel B	**Model with interaction**		
0.766	0.898 (0.3834)	5.056 (0.022)	0.736 (0.721)

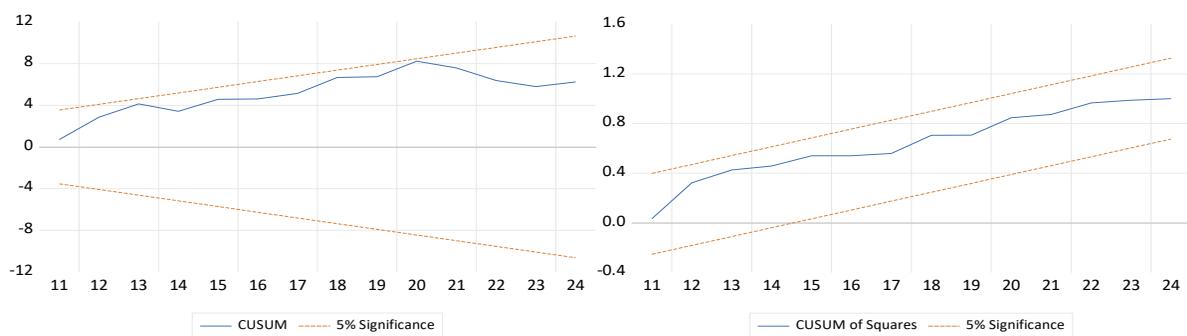**Note:** Probability values for the post-estimation test are in parentheses.

Figure 4. CUSUM and CUSUM Square for Model without interaction term.
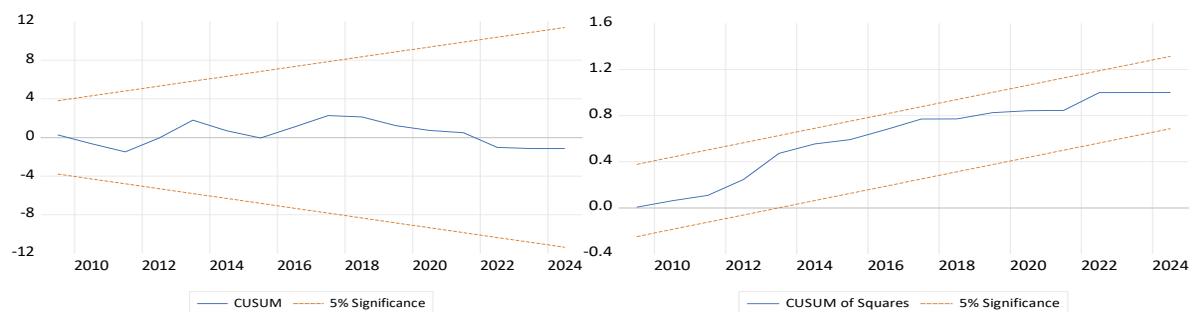

Figure 5. CUSUM and CUSUM Square for Model with interaction term.

5. Conclusion

We revisit the external financing and environmental sustainability nexus, considering the role of institutional quality in Nigeria from 1990 to 2024, incorporating the external financing index, institutional quality index, capital, labor force, and exchange rate as additional important factors in the carbon dioxide emission model. The outcome was further validated using the model of natural resource depletion as a proxy for environmental sustainability. This empirical attempt, being quite different from existing studies, makes our study most unique and contributes to international economics, environmental economics, and policy literature on Nigeria (Awodumi & Adewuyi, 2020;

Egbetoku et al., 2019; Iheanachor & Ozegbe, 2021; Kareem et al., 2012; Ominyi & Adayi, 2017). First, the results emanating from the model without interaction indicate that external financing significantly increases CO_2 emissions, thereby worsening environmental sustainability, whereas capital and institutional quality exhibit potential to keep its level low over short-run and long-run horizons. This is further corroborated by the model with an interactive term revealing that external financing-institutional quality (EXF*IQI) substantially influences the increase in CO_2 emissions.

In order to validate the model of environmental sustainability using carbon dioxide emission, this study employed natural resource depletion as a proxy, and the result without the interactive term reveals that external financing leads to natural resource depletion, thereby exacerbating environmental sustainability. We further interact institutional quality with external financing, and the outcomes still align with the earlier result of a significant positive effect on CO_2 emission. These outcomes from the four models validate Kuznets' hypothesis in Nigeria and further prove that external financing is deleterious to environmental sustainability in Nigeria. Furthermore, the results of the models also substantiate that the existing institutional framework is still very weak to facilitate effective utilization of external financing in Nigeria. Nigeria stands at a critical crossroads where financial growth must harmonize with environmental stewardship. By transforming weak institutional structures into dynamic, accountable systems and embedding environmental sustainability directly into financial agreements, the country can revolutionize its approach to external financing. This strategic approach doesn't just mitigate ecological risks it reimagines development as a balanced dance between economic progress and environmental preservation.

This research ultimately contributes to the validation of the Kuznets hypothesis by highlighting that the environmental impact of external financing is not inherently deterministic but deeply dependent on institutional quality. The findings emphasize that effective utilization of external financing requires a strong institutional framework, where efficient governance acts as a crucial moderator in mitigating potential environmental degradation. By examining the complex interactions between external financing, institutional quality, and environmental indicators, the research provides a distinct perspective that challenges simplistic views of economic development, emphasizing that sustainable progress demands more than mere external resources it necessitates strategic institutional management and a comprehensive approach to environmental preservation.

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