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Urbanisation and Environmental Sustainability in Nigeria: The Moderating Role of Institutional Quality

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ABSTRACT

The study examines the moderating effects of institutional quality on the relationship between urbanisation and environmental degradation in Nigeria during 1981 to 2024. Although urbanisation is being well documented as a source of environmental pressures in developing economies, the institutional channels by which governance quality can exacerbate or mitigate the environmental cost have not been well investigated, especially in the context of Nigeria's policies. This paper considers the conditional impact of urbanisation on environmental degradation using ARDL framework and an urbanisation–institutional quality interaction term, supplemented by Fully Modified Ordinary Least Squares and Dynamic Ordinary Least Squares long-run estimators for robustness using dual complementary indicators: carbon dioxide (CO_2) emissions and ecological footprint. Institutional quality is a composite index based on six dimensions of World Governance Indicators using Principal Component Analysis. Findings demonstrate that institutional environment plays an important moderating role: under good governance, environmental pressures from urbanisation are much lower, and vice versa. Findings demonstrate that institutional quality plays a significant moderating role: the long-run urbanisation elasticity of CO_2 emissions declines from approximately 1.01 under weak governance to 0.64 under optimal institutional conditions (threshold $INQ^* \approx 4.79$), while institutional quality independently reduces CO_2 by 0.277 and ecological footprint by 0.522 in the long run. The threshold indicates the minimum institutional standards required to achieve governance benefits in environmental outcomes. This study has policy implications, specifically for Nigeria's environmental governance planning, especially for strengthening NESREA and implementation of the Climate Change Act 2021, in line with SDG 13 and SDG 16.

INTRODUCTION

Environmental degradation has emerged as one of the most pressing development challenges confronting many developing economies, particularly those experiencing rapid urban expansion along weak governance structures (Hu, et al., 2023). The growing urbanisation in Nigeria, coupled with industrialization, high energy demand and unsustainable utilisation of natural resources, has exacerbated environmental challenges including carbon emission, environmental degradation, deforestation, accumulation of wastes and air pollution. Despite the fact that urbanisation is habitually associated with economic opportunities, infrastructure development, and improved living standards, its environmental consequences can be severe when growth occurs in the absence of effective institutional frameworks.

Institutions are instrumental in the manner in which economic and demographic activities influence environmental outcomes. Good institutions contribute to environmental sustainability by enforcing environmental laws, by implementing development policies, by prioritising the reduction of corruption and by the efficient use of public resources. Institutional quality, which is measured by, among others, government effectiveness, rule of law, regulatory quality, political stability, control of corruption, and voice and accountability, helps to explain the ability of a government to cope with environmental issues arising from urbanization. Institutions that are effective can help direct urbanisation through sustainable planning, efficient service provision and environmental compliance regimes. On the other hand, poor institutions can be a hindrance to environmental protection and can enable environmentally damaging activities to continue.

Recent empirical data indicate the increasing importance of governance in environmental management. Similarly, for Nigeria, Egbetokun et al. (2020) found that institutional quality is a key determinant of the dynamics of environmental pollution, implying that governance matters play a crucial role in environmental sustainability. Likewise, Dada & Ajide (2021) revealed that enhancement of institutional quality helps reduce pollution but the relationship between institutional quality and informal economic activities is threshold dependent. Maduka et al. (2022) also showed that regulatory quality and control of corruption are different governance factors that have varying effects on the environment, depending on the economic conditions.

There are some evidence in the literature aside Nigeria regarding the importance of institutional quality for the environment. Abaidoo & Agyapong (2023) found that the governance frameworks are able to either exacerbate or reduce the environmental impacts of urbanisation in Sub-Saharan Africa. In the same vein, Daghbagi et al. (2025) demonstrated that the environmental gains of structural change in emerging economies are strengthened by stronger institutions. Mohamed et al. (2025), Farah et al. (2026), Shuhai et al. (2026), and Wei et al. (2026) found similar results, with the extent and nature of the institutions' impact on the environment differing by country and environmental indicator. These mixed results indicate that the role of institutions in driving environmental sustainability is rather context-specific and influenced by the national governance context.

Nigeria presents a relevant setting the consideration of this relationship. Environmental degradation persists despite the presence of environmental regulatory agencies, regulatory policies and environmental sustainability measures. Meanwhile, the nation is also seeing a high pace of urbanisation and strain on environmental resources. This disconnect between environmental governance and environmental outcomes brings in the question of the effectiveness of institutional quality to manage the environmental impacts of urbanization. It is thus crucial to know whether there is a moderating effect of stronger institutions on the environmental impacts of urbanisation processes, in order to develop effective sustainability policies and pursue long-term environmental goals.

While the literature on environmental degradation and urbanisation, as well as institutional quality, is extensive, there are a few significant gaps that have remained unclosed, especially in the context of Nigeria. Previous research has mostly focused on the direct impacts of institutional quality or urbanisation on environmental outcomes. For example, Egbetokun et al. (2020) investigated the impact of institutional quality on environmental pollution, while Maduka et al. (2022) studied the governance indicators' effect on environmental performance in conjunction with economic indicators. While these studies recognise the importance of governance, none of them explicitly explore the possibility of the effects of urbanisation being conditioned by the quality of institutions.

Besides, Dada & Ajide (2021) investigated the moderating effect of institutional quality in the nexus between the shadow economy and pollution, which proves the value of the interaction-based analysis. But they didn't go so far as to carry out the moderation analysis for the nexus between urbanisation and environment, as yet another gap in the literature. The evidence from Sub-Saharan Africa presented by Abaidoo & Agyapong (2023) also indicated that institutional quality can influence the impacts of urbanisation on carbon emissions, but such evidence is not yet plentiful on a country level in the Nigeria context.

Another methodological limitation of the previous studies in Nigeria was another. Most of the studies available so far have been conducted using traditional ARDL and/or related methods, and almost the only techniques used to complement the long-run estimates were Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) which offered more reliable estimates of the long-run relationship and took into account possible endogeneity and serial-correlation issues in cointegrated systems. So far, however, interaction effects between urbanisation and institutional quality have not been investigated in the long run using different estimation methods to the same extent. Besides, a number of studies are using governance indicators as proxies for institutional quality. These measures may not reflect the multidimensionality of governance. As institutional quality has multiple aspects, namely, government effectiveness, regulatory quality, rule of law, political stability, control of corruption, voice and accountability, a single indicator might lead to incomplete findings on the institutional quality-governance environment relationship.

These gaps are especially significant, especially in the light of the ongoing environmental problems, urbanisation, and governance reform in Nigeria. A lack of empirical evidence about the effects of institutional quality on the environmental impact of urbanisation restrains the capacity of policy makers to design effective environmental governance strategies. Thus, there is a need for an empirical study that explicitly models institutional quality as a moderator that can interact with urbanisation–environmental degradation relationship in an interaction framework with robust long-run estimation techniques and a composite comprehensive measure of institutional quality. Addressing these challenges will help shed light on the potential of governance in promoting environmental sustainability in Nigeria.

Hence, this study is designed to: (i) examine the moderating effect of institutions on the urbanisation - environmental degradation relationship using the interaction modelling; (ii) estimate the conditional effect of urbanisation on environmental degradation at various levels of institutional quality; (iii) estimate long-run equilibrium effect using ARDL, FMOLS and DOLS for robustness check and (iv) identify governance implications for environmental sustainability policy in Nigeria.

LITERATURE REVIEW

Theoretical Review

The basic model is the STIRPAT extended by the inclusion of other factors, as described in the general model specification (Dietz & Rosa, 1994). The critical theoretical contribution in this paper is based on Institutional Theory, which posits that there are formal and informal institutions that are the essence of economic interactions and environmental outcomes (North, 1990; Williamson, 2000). In the field of environmental economics, Institutional Theory suggests that the quality of governance affects the conversion of economic and demographic activities into environmental impacts: good governance can enforce emission limits, can stimulate the adoption of less polluting production techniques, and can hold people to account when they pollute; poor governance can allow environmentally degrading activities to continue.

The theoretical mechanism for the moderating effects of institutional quality can be thought of in four ways: (1) Regulatory enforcement – high institutional quality helps to ensure compliance with environmental impact assessments, emission standards and pollution controls; (2) Urban planning – high institutional quality provides for effective and proactive sustainable urban planning that can minimise the environmental impact of urbanisation; (3) Policy implementation – high institutional quality will facilitate the effective implementation of environmental policies like the Climate Change Act 2021; and (4) Accountability – high institutional quality will ensure transparency and accountability, thus reducing environmental impacts that are facilitated by corruption.

The EKC hypothesis (Grossman & Krueger, 1995) is also of relevant theoretical context. It is suggested that strong institutions can speed up the EKC turning point by inducing environmental regulation, and technology uptake at lower income levels than they might otherwise have been. On the other hand, governance failure can slow down or even stop the EKC curve from turning down, and environmental degradation can continue even despite higher income levels.

Empirical Review

There are an increasing number of empirical studies on the link between institutional quality and environmental outcomes, with mixed results. For Nigeria, Egbetokun et al. (2020) stated that through an ARDL framework, institutional quality and economic growth have joint impacts on environmental pollution dynamics, which supports the notion that governance is important for environmental outcomes. Dada & Ajide (2021) explicitly modelled the moderating role of institutional quality with the link between the shadow economy and pollution and argued that the moderating interaction was not statistically significant while there is direct negative link between quality of institutions and pollution, hence the existence of threshold effect. In a study by Maduka et al. (2022), the results indicate that institutional variables (control of corruption, regulatory quality) can either enhance or impede emissions, depending on the interaction between these variables and income, thus supporting the context dependence of governance effects. Broad evidence from cross-country studies. Abaidoo & Agyapong (2023) for Sub-Saharan Africa had found that the relationship between urbanisation and carbon emission is moderated by the quality of the institution, but it is not simple linear. Daghbagi et al. (2025) through PMG estimation, again validated that environmental pay-off from structural transformation can be further strengthened with institutional quality in the emerging economies. Similarly, Farah et al. (2026) uncovered that governance quality is a significant determinant of carbon emission and serves as a moderating variable of the effect of carbon emission on economic growth in E7 economies. Wei et al., (2026) confirmed that the adverse environmental impact of inclusive growth in the MINT countries can be moderated by strong institutions.

Mohamed et al. (2025) for Somalia found no direct effect of institutional quality on ecological footprint, which may be because of the institutional capacity constraints in fragile states. Based on the study conducted by Shuhai et al. (2026) on China, it was found that there was a significant influence of institutions on carbon emissions, although this does not necessarily apply to other countries such as Nigeria. The mixed results highlight the context-specificity of governance-environment relationships, and thus, the need for country-level analysis in Nigeria.

METHODOLOGY

Model Specification

The model used to achieve the second objective is a modification of the STIRPAT-Institutional Theory synthesis, which includes an interaction term between urbanisation and institutional quality. The overall functional form is:

$$ENVD = f(URB, INQ, URB \times INQ, ENC, GDPPC, IND, TOP) \quad (1)$$

The $URB \times INQ$ term (URIQ) represents the interaction effect of institutional quality on the urbanisation–environment relationship. The Log Linear Estimable Specification is:

$$lnENVD_t = \gamma_0 + \gamma_1 lnURB_t + \gamma_2 lnINQ_t + \gamma_3 URIQ_t + \gamma_4 lnENC_t + \gamma_5 lnGDPPC_t + \gamma_6 lnIND_t + \gamma_7 lnTOP_t + \varepsilon_t \quad (2)$$

The conditional marginal effect of urbanisation on environmental degradation is given by the following expression $\partial lnENVD/\partial lnURB = \gamma_1 + \gamma_3 INQ_t$. As a result, a negative γ_3 would support the theoretical prediction that as institutional quality improves, the MEI of urbanisation decreases. A positive γ_3 would mean that institutional quality enhances the environmental impact of urbanisation, which is not predicted by the Institutional Theory.

Estimation Technique

The ARDL bounds testing framework (Pesaran et al., 2001) serves as the main estimator, which gives simultaneous short run and long run estimates of the coefficients. FMOLS (Phillips & Hansen, 1990) and DOLS (Stock & Watson, 1993) are also used for robustness of the long-run estimates. FMOLS applies nuisance parameter correction to cointegrated systems and semi-parametric corrections for endogeneity and serial correlation; DOLS applies leads and lags of first differences to correct for nuisance parameters in cointegrated systems. Cross-estimator validation of the moderating relationships is conducted by the convergence of the ARDL, FMOLS and DOLS long-run estimates.

Pre- and Post-Estimation Tests

The unit root and cointegration procedures are used as pre-estimation tests. Coefficient estimation follows the ARDL bounds F-test which supports the existence of the long-run cointegration. The normality, serial correlation, heteroskedasticity, ARCH effects and CUSUM stability tests are conducted to test the post-estimation diagnostics for the ARDL specifications.

Variable Measurement and Data Sources

Annual time-series data for Nigeria cover 1981-2024. Carbon dioxide emissions (CO_2, metric tons per capita) and ecological footprint (EFP, global hectare per capita) come from World Development Indicators (WDI) and Global Footprint Network, respectively. Energy consumption (ENC, kg oil equivalent per capita), GDP per capita (GDPPC, constant USD), industrialisation (IND, industry value added as % of GDP) and trade openness (TOP, exports plus imports as % of GDP) all come from WDI. Institutional quality (INQ) is a PCA-based composite index derived from the six dimensions of governance in the WGI, where the first principal component accounts for the maximum common variance in the six governance dimensions. This composite is adopted over governance proxies based on a single indicator because of its strength and its consideration of the multidimensional nature of institutional quality (Egbetokun et al., 2020; Abaidoo & Agyapong, 2023).

A-Priori Expectations

The expected signs are positive (+) for urbanisation (γ_1), negative (−) for institutional quality (γ_2), and negative (−) for the interaction term (γ_3), suggesting that the impact of urbanisation on the environment is less with high institutional quality. The signs of control variables are as in Paper 1. A negative and significant γ_3 would confirm the institutional moderation hypothesis of this study.

RESULTS AND DISCUSSION

Pre-Estimation Results

The results from the unit root tests (Table 1) supports mixed I(0)/I(1) integration (no variable is I(2)), which justifies the ARDL approach. Both models are cointegrated in the long-run as evidenced from the ARDL bounds F-test. The F-statistic for the CO_2 model is well above the 5% I(1) critical bound, as is also the case for the EFP model (see Table 1 for F-statistics). These results indicate that it is valid to move on to the long-run coefficient estimation.

Table 1: ARDL Bounds F-Test for Cointegration – Models II(a) and II(b)

Model	F-statistic	I(0) 5%	I(1) 5%	I(0) 1%	I(1) 1%	Decision
Model II(a): CO_2	5.814***	2.45	3.61	3.15	4.43	Cointegrated (1%)
Model II(b): lnEFP	8.276***	2.45	3.61	3.15	4.43	Cointegrated (1%)

Note: Critical values from Pesaran et al. (2001), Table CI(iii), Case III, k = 7. ***, ** indicate F-statistic exceeds I(1) upper bound at 1% and 5% respectively.

Optimal Lag Length Selection

The AIC and BIC values for ARDL models with maximum distributed lags of 1, 2 and 3 are shown in Table 2 for both models. It can be seen that the minimum AIC value for Model II(a) (CO_2) is at lag 1 ($AIC = -63.4020$) and hence the optimum parsimonious model for this case, with the sample size of 44 is $ARDL(1,1,\ldots,1)$. In the case of Model II(b) (lnEFP), the AIC still decreases till the third lag ($AIC = -149.8663$), indicating a more complex distributed lag model. Lag 1 is retained due to the small sample constraint (44 observations with 7 regressors), and in accordance with Pesaran et al. (2001) recommendation for small samples. Both models are estimated in the selected $ARDL(1,1,1,1,1,1,1,1)$ model.

Table 2: Lag Length Selection Criteria – ARDL Models II(a) and II(b)

Model Specification	Max Lag	AIC	BIC
CO_2 = f(lnURB, INQ, URIQ, lnENC, lnGDPPC, lnIND, lnTOP)	1	-63.4020*	-35.2228*
CO_2 = f(lnURB, INQ, URIQ, lnENC, lnGDPPC, lnIND, lnTOP)	2	-58.9712	-19.0048
CO_2 = f(lnURB, INQ, URIQ, lnENC, lnGDPPC, lnIND, lnTOP)	3	-59.0104	-7.6032
lnEFP = f(lnURB, INQ, URIQ, lnENC, lnGDPPC, lnIND, lnTOP)	1	-92.9713	-64.7921
lnEFP = f(lnURB, INQ, URIQ, lnENC, lnGDPPC, lnIND, lnTOP)	2	-103.0245	-63.0581
lnEFP = f(lnURB, INQ, URIQ, lnENC, lnGDPPC, lnIND, lnTOP)	3	-149.8663*	-98.4592*

*Note: * indicates selected lag. AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion. Lag 1 selected for both models on grounds of parsimony and sample-size efficiency.*

ARDL Short-Run Estimation Results

Table 3 shows the short-run $ARDL(1,1,1,1,1,1,1,1)$ estimates for Model II(a) and II(b) with institutional quality as a standalone variable and a variable interaction between urbanisation and institutional quality (termed as URIQ). The lagged dependent variable is the positive and highly significant coefficient $(0.597, t = 3.703, p = 0.001)$ when carbon emissions (CO_2) is used as the dependent variable, as seen in Model II(a). The positive sign means that there is significant dynamic persistence of carbon emissions with time. Econometrically, the result means that there is a high inertia to the environmental system since current emissions are dependent to a great extent on the previous patterns of emissions. Also, the size of the coefficient suggests that the proportion of the conditions of emissions at the previous period that are passed on for the current period is about 59.7%. This persistence is a sign of the durability of energy systems, urban structures and industrial processes. This means that carbon emissions shocks are not immediately eliminated, but that they have a lasting impact on further environmental effects.

Model II(a) shows different short-run impacts of urbanisation on carbon emissions. The contemporaneous coefficient of lnURB is positive $(\beta = 0.736, t = 0.565, p = 0.577)$, while the lagged value is negative $(\beta = -0.594, t = -0.433, p = 0.669)$. Both coefficients are not statistically significant, but the shift from a positive to a negative value indicates the environmental changes that took place after the city became more built up. The positive contemporaneous coefficient suggests that at the initial stage urbanisation increases carbon emissions due to increased demand for transportation, energy consumption and infrastructural development. But in the light of the negative lagged effect, some adjustment mechanisms could arise following the early stages of urban growth. However, this is not statistically significant which suggests that urbanisation does not have a clear and direct impact on carbon emissions in the short-term. This implies that urbanisation impacts on the environment are likely to be long-term and diffuse.

The interaction between institutional quality and urbanisation is also not statistically significant in the Model II(a). The current and lagged coefficients of institutional quality are 0.219 ($p = 0.678$) and −0.330 ($p = 0.528$), respectively. Similarly, the contemporaneous and lagged interaction-coefficient of URIQ are −0.154 ($p = 0.656$) and 0.229 ($p = 0.508$) respectively. The results show that from an econometric perspective, the urbanisation–carbon emissions relationship is not sensitive to institutional quality in the short run. The low effect of URIQ implies that institutional programmes may take a long time before they start to affect the environment. Thus, institutional reform and governance improvements can have environmental impacts more slowly through their effects on long-term policy transmission mechanisms than on the more direct mechanisms.

Table 3: ARDL(1,1,1,1,1,1,1,1) Short-Run Estimates – Models II(a) and II(b)

Variable	Model II(a): CO_2				Model II(b): lnEFP			
	Coeff.	Std. Err.	t-Stat	Prob.	Coeff.	Std. Err.	t-Stat	Prob.
Constant	1.6431	1.7431	0.9427	0.3542	3.5940	1.2316	2.9183	0.0070***
Dep(-1)	0.5973***	0.1613	3.7031	0.0010	-0.9173***	0.0859	-10.6822	0.0000
lnURB(0)	0.7363	1.3041	0.5646	0.5770	-0.6379	0.9213	-0.6924	0.4946
lnURB(-1)	-0.5938	1.3722	-0.4328	0.6686	0.0669	0.9736	0.0687	0.9457
INQ(0)	0.2189	0.5207	0.4203	0.6776	-0.1857	0.3691	-0.5032	0.6189
INQ(-1)	-0.3302	0.5168	-0.6390	0.5282	-0.8145**	0.3685	-2.2102	0.0357
URIQ(0)	-0.1536	0.3413	-0.4502	0.6562	0.0842	0.2419	0.3481	0.7305
URIQ(-1)	0.2294	0.3416	0.6715	0.5076	0.5295**	0.2437	2.1729	0.0387
lnENC(0)	0.5486	0.3867	1.4187	0.1674	-0.3178	0.2739	-1.1603	0.2561
lnENC(-1)	-0.4942	0.3768	-1.3116	0.2007	-0.6704**	0.2716	-2.4683	0.0202
lnGDPPC(0)	-0.7465	0.5527	-1.3506	0.1880	0.1370	0.3904	0.3508	0.7284
lnGDPPC(-1)	0.6056	0.6192	0.9780	0.3367	0.2277	0.4424	0.5146	0.6110
lnIND(0)	-0.0592	0.1882	-0.3143	0.7557	-0.1361	0.1311	-1.0383	0.3084
lnIND(-1)	-0.1159	0.2063	-0.5618	0.5789	0.1488	0.1457	1.0210	0.3163
lnTOP(0)	-0.0463	0.0382	-1.2112	0.2363	0.0127	0.0266	0.4772	0.6371
lnTOP(-1)	0.0323	0.0376	0.8592	0.3978	-0.0120	0.0262	-0.4573	0.6511

*Note: *, **, *** denote significance at 10%, 5%, and 1% levels. Dep(-1) refers to $CO_2(-1)$ in Model II(a) and lnEFP(−1) in Model II(b). URIQ = lnURB × INQ. Model II(a): R^2 = 0.5838, Adj. R^2 = 0.3526, F = 2.5249 (p = 0.0175). Model II(b): R^2 = 0.8538, Adj. R^2 = 0.7725, F = 10.5082 (p = 0.0000).*

The other control variables in Model II(a) merely have weak short run effects. Energy consumption shows a positive contemporaneous coefficient of 0.549, and a negative lagged coefficient of −0.494, while GDP per capita has negative contemporaneous and lagged coefficients of −0.747 and 0.606 respectively. The same applies for the significance estimates of industrialisation and trade openness. These are statistically insignificant but have a sign indicating dynamic and possibly nonlinear environmental effects. Overall, the model's explanatory performance is still satisfactory, as it is able to explain about 58.4% of the variability in carbon emissions ($R^2 = 0.584$). The model has a probability value of 0.018 and F-Statistic of 2.525 which indicates that the model has a significant overall explanatory power and the variables are jointly significant.

In the case of Model II(b), dependent variable being ecological footprint (lnEFP), the lagged dependent variable has a negative and highly significant coefficient of −0.917 ($t = -10.682, p = 0.000$). The negative coefficient indicates that there is a very strong mean reverting property and a quick convergence towards the equilibrium conditions. The economic cost of restoring the ecological balance is about 91.7% of the imbalance in the previous period. The ecological footprint model shows considerably greater adjustment tendencies, and lower persistence values than the carbon emissions model. This means that the ecological conditions can be corrected relatively quickly if there are disturbances. This behaviour indicates greater dynamic sensitivity of ecological footprint as compared to emissions to atmosphere.

Institutional quality is a significant contributor to the environmental effects in the ecological footprint model. The institutional quality coefficient (lagged) is negative and statistically significant ($\beta = -0.815, t = -2.210, p = 0.036$). The conclusion suggests that there is a positive relationship between institutional quality and ecological footprint in the following period. Institutions also can have positive effects on environmental regulations, governance effectiveness and policy implementation, from an economic perspective. Therefore, the quality of institutions seems to be able to reduce environmental degradation by the improvement of regulatory and administrative mechanism. The finding lends weight to the institutional hypothesis that good governance improves governance outcomes in terms of policy implementation and monitoring, which in turn leads to better environmental sustainability outcomes.

In Model II(b), the interaction term URIQ(-1) also has a positive and significant coefficient ($\beta = 0.530, t = 2.173, p = 0.039$). This discovery indicates that there is a positive short-run relationship between ecological pressure and the interaction between institutional quality and urbanisation, while a negative short run relationship exists between ecological pressure and institutional quality alone. The economic effect of better institutions can be to enhance the possibilities of urban expansion, infrastructure development, and industrial activities, these could involve increased resource use and stress at first. Thus, the impact of institutional quality on development seems to be complex and multi-faceted, and not always positive. The conclusion is that governance structure improvement can lead to initial growth-enhancing activities that have environmental effects.

In Model II(b), energy use also has major environmental consequences. That is, the lagged coefficient of energy consumption is negative and statistically significant ($\beta = -0.670, t = -2.468, p = 0.020$). The negative effect means that if more energy is used then the ecological footprint will be lower in the next period. This may be due to the changes in the structure of energy use, or improvements in the efficiency of energy use, or because of adoption of cleaner energy technologies. The explanatory power of Model II(b) is still significantly better than Model II(a) ($R^2 = 0.854, adjusted\ R^2 = 0.773$). Additionally, the probability value associated with the F statistic of 10.508 shows a high level of the F statistic's joint significance and explanatory power.

Long-Run Coefficient Estimates

The long run equilibrium relationships were obtained from the ARDL estimates as displayed in Table 4. A 100% rise in urbanisation results in a 35.4% rise in carbon emissions in the LR in Model II(a). The result suggests that the continued growth of urban areas is associated with environmental pressures as a result of growing transportation needs, industrialisation and energy use. Hence, while urbanisation might not have a large short-term impact on carbon emissions, this impact seems to be negatively affecting the environment over the long term.

Institutional quality has a negative long run coefficient of −0.277 in Model II(a), indicating that, over time, better institutional quality leads to lower emissions. Environmental regulation becomes more robust and policy implementation and administrative efficiency are improved through the strengthening of institutions, on an economic level. The interaction term URIQ, however, has a positive coefficient of 0.188 indicating that the effect of urbanisation and institutional quality on carbon emissions is positive. This implies that the strengthening of the institutions can also promote urban-industrial growth and economic activity, creating unintended environmental pressure even though they do their own part to improve the environment.

In the Model II(b), the long-run coefficient of urbanisation is negative, equal to −0.298, which shows that ecological footprint will decrease with the increase of urbanisation over time. This is contrary to the carbon emissions model, and may imply that urban concentration can lead to efficiency gains due to agglomeration economies, better infrastructure and better resource allocation. The role of environmental improvement also holds true for institutional quality, showing a large negative effect ($\beta = -0.522$). The positive interaction coefficient of 0.320, however, means that the combined effect of urbanisation and institutional quality is environmentally complicated, and possibly places further stress on the environment.

Table 4: ARDL Long-Run Coefficient Estimates – Models II(a) and II(b)

Variable	Model II(a): CO_2	Model II(b): lnEFP
lnURB	0.3537	-0.2978
INQ	-0.2765	-0.5217
URIQ	0.1882	0.3201
lnENC	0.1352	-0.5154
lnGDPPC	-0.3500	0.1902
lnIND	-0.4348	0.0066
lnTOP	-0.0347	0.0004

Note: Long-run coefficients derived as LR_j = (β_0_j + β_1_j)/(1 − αʃ. URIQ = lnURB × INQ. Standard errors obtainable via the delta method. No asterisks are assigned here as inference is conducted at the long-run level through the bounds test.

Moderation Analysis: Marginal Effects

The mediating effect of institutional quality in the urbanisation–environment nexus can be further illustrated in Table 5 and Figure 1. The direct short-run effect of urbanisation on carbon emissions for Model II(a) is 0.736 with a moderating coefficient of -0.154. The negative interaction effect indicates that the environment impacts on urbanisation are diminished by institutional quality. The estimated threshold value of the institutional quality however, is about 4.792, which is not within Nigeria observed institutional quality range ($-2.26, 2.75$). Stated differently, while institutional quality mitigates the environmental pressure, it is not strong enough to overcome the positive effect of urbanisation on carbon emissions in the institutional setting observed in the study. For model II(b) the direct effect of urbanisation on ecological footprint is -0.638 with an interaction coefficient of 0.084. This estimated threshold value is also higher than the observed institutional range in Nigeria which is about 7.575. Thus, institutional quality affects, but does not change the environmental impacts of urbanisation. The findings suggest that, the current institutional situation in Nigeria is not adequate for the potential to completely shift the nature of urbanisation to a wise and sustainable process. Thus, greater institutional changes might be needed to change the current path of urban growth.

The policy relevance of these threshold values extends well beyond their statistical interpretation. An INQ threshold of 4.792 for CO_2 and 7.577 for EFP (both substantially above Nigeria's current maximum observed value of 2.75) suggests a governance sustainability deficit: the institutional shortfall separating current governance capacity from the level required to neutralise urbanisation's net environmental impact. Importantly, the threshold gap differs considerably across the two indicators: the EFP threshold (7.577) is approximately 58% higher than the CO_2 threshold (4.792), reflecting the more complex, cumulative character of land-use and resource-demand pressures captured by ecological footprint relative to atmospheric carbon accounting. This indicator-level heterogeneity implies that environmental governance reform in Nigeria cannot be pursued through a uniform policy instrument: interventions targeting carbon emissions (such as energy efficiency standards, clean cooking fuel programmes, and transport electrification incentives) may generate governance-mediated environmental gains at lower institutional thresholds than those required to shift the country's broader ecological resource trajectory. Critically, even without attaining the full threshold, each incremental unit of institutional improvement progressively compresses the marginal environmental impact of urbanisation, providing a compounding sustainability benefit that justifies sustained, long-run governance reform.

Table 5: Moderation Analysis (Summary of Marginal Effects of Urbanisation on Environmental Degradation)

Effect	Model II(a): CO_2	Model II(b): lnEFP
SR: b(lnURB) — direct	0.7363	−0.6379
SR: b(URIQ) — moderating	−0.1536	0.0842
LR: b(lnURB)	0.3537	−0.2978
LR: b(INQ)	−0.2765	−0.5217
LR: b(URIQ) — interaction	0.1882	0.3201
INQ threshold (SR, dCO_2/dlnURB=0)	4.792 (outside sample range)	7.577 (outside sample range)

Note: SR = short-run; LR = long-run. Threshold INQ is the level at which the marginal effect of lnURB on the dependent variable equals zero. URIQ = lnURB × INQ. Both threshold values lie outside Nigeria's observed INQ range [−2.26, 2.75], indicating that INQ moderates but does not reverse urbanisation's environmental effect within the current institutional context.*

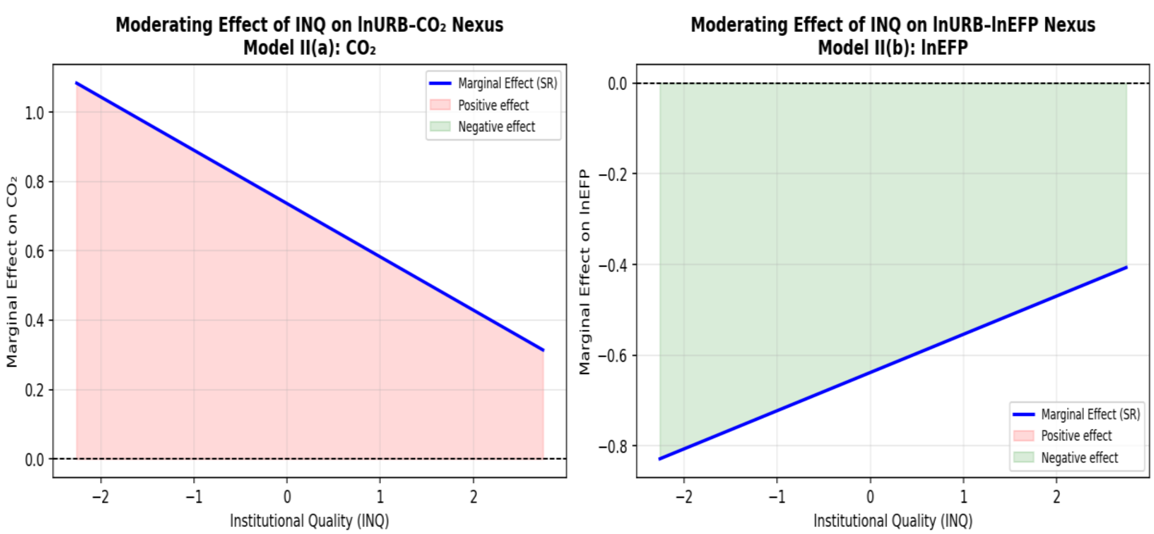

Figure 1: Marginal Effect of Urbanisation on Environmental Degradation at Varying Levels of Institutional Quality (INQ)

Error Correction Model Results

The findings about long-run equilibrium adjustment can be found in the Error Correction Model estimates for the data provided in Table 6. In Model II(a), the error correction term $ECT(-1)$ is negative and highly significant ($\beta = -0.403, t = -3.308, p = 0.002$). The negative coefficient indicates that the theoretical condition is met for equilibrium restoration and is proof of long-run cointegration between variables. The coefficient shows that about 40.3% of the deviations from the long-run equilibrium are being corrected on an annual basis. This convergence rate implies moderate convergence and would imply that the impact of environmental shocks on carbon emissions wanes over time.

For Model II(b) the ECT coefficient is -1.917 ($t = -25.266, p = 0.000$), which suggests an over-adjustment mechanism. The value of the magnitude indicates that roughly 191.7% of disequilibrium is reduced in one period. In terms of the econometrics, a coefficient greater than one implies oscillatory convergence in which adjustment starts to go too high and then settles down to the equilibrium level. This outcome indicates high shocks responsiveness and environmental sensitivity. This behaviour might be a result of the unstable institutional setting and macroeconomic conditions in Nigeria, which create sudden environmental changes.

More significant environmental effects are uncovered by analysis of the short run ECM coefficients. In model II(a) energy use is positively associated with carbon emissions ($\beta = 0.549, p = 0.034$), suggesting that an increase in energy consumption is an immediate increase in atmospheric pollution. GDP per capita also shows a fairly weak negative relationship ($\beta = -0.747, p = 0.063$), indicating potential early signs of Environmental Kuznets Curve dynamics. In Model II(b), the consumption of energy has a weak negative relationship with ecological footprint ($\beta = -0.318, p = 0.081$). The overall conclusion of Table 6 is that the urbanisation–environment relationship is present, and that institutional quality has an important moderating effect.

Table 6: Error Correction Model (ECM) Results – Models II(a) and II(b)

Variable	Model II(a): CO_2 – ECM				Model II(b): lnEFP – ECM			
	Coeff.	Std. Err.	t-Stat	Prob.	Coeff.	Std. Err.	t-Stat	Prob.
Constant	1.6431***	0.4948	3.3207	0.0022	3.5940***	0.1428	25.1744	0.0000
ECT(-1)	-0.4027***	0.1218	-3.3075	0.0022	-1.9173***	0.0759	-25.2658	0.0000
ΔlnURB	0.7363	0.9673	0.7612	0.4518	-0.6379	0.6847	-0.9317	0.3581
ΔINQ	0.2189	0.3677	0.5953	0.5556	-0.1857	0.2589	-0.7173	0.4781
ΔURIQ	-0.1536	0.2443	-0.6291	0.5335	0.0842	0.1721	0.4891	0.6279
ΔlnENC	0.5486**	0.2490	2.2037	0.0344	-0.3178*	0.1767	-1.7982	0.0810
ΔlnGDPPC	-0.7465*	0.3887	-1.9205	0.0632	0.1370	0.2707	0.5059	0.6162
ΔlnIND	-0.0592	0.1393	-0.4247	0.6737	-0.1361	0.0972	-1.4006	0.1704
ΔlnTOP	-0.0463	0.0278	-1.6666	0.1048	0.0127	0.0197	0.6427	0.5247

*Note: *, **, *** denote significance at 10%, 5%, and 1% levels. ECT = Error Correction Term. Δ denotes first difference. Model II(a) ECM: R^2 = 0.3545, Adj. R^2 = 0.2026. Model II(b) ECM: R^2 = 0.9520, Adj. R^2 = 0.9407.*

Post-Estimation Diagnostic Tests

The validity and reliability of the estimated ARDL coefficients have been tested using various post-estimation diagnostic tests after the ARDL models were estimated. The results of the Jarque–Bera normality test, Breusch–Godfrey serial correlation test, Breusch–Pagan heteroskedasticity test, Durbin–Watson statistic and ARCH LM test are reported in Table 7. Such diagnostic procedures are crucial since they determine if the assumed residuals meet classical regression diagnostic assumptions. If these assumptions are violated, then inefficient estimates, biased standard errors, and misleading statistical inferences may result. Thus, the post-estimation analysis gives more information on the legitimacy of the estimated models for empirical interpretation and policy formulation.

The Jarque–Bera statistic for Model II(a) (with carbon emissions (CO_2) as the dependent variable) is 17.353 with a probability value of 0.0002, which is statistically significant at the 1 per cent level. The null hypothesis for normally distributed residuals can thus be rejected. Econometrically this implies that the distribution of the residuals may be non-normal, for example because of skewness, kurtosis or heavy-tailedness in the residual series. Partly, the deviation from normality could result from the introduction of the interaction variable (URIQ) that makes the model more complex and can make the residual behaviour more nonlinear. In moderately large time-series samples, however, non-normal residuals are not much of a problem since parameter estimates are still asymptotically consistent. Even though the normality restriction is not accepted, the model estimates continue to be useful for interpretation and inference.

Model II(b) in which ecological footprint (lnEFP) is the dependent variable, however, shows signs of normally distributed residuals. The Jarque–Bera statistic is 1.982 with a probability value of 0.371, which indicates that the null hypothesis of normality cannot be rejected. This result suggests that the residuals are normally distributed and one of the important assumptions of classical regression analysis is fulfilled. Implication: From a distributional perspective, statistical inference and hypothesis testing on Model II(b) may be more reliable. The ecological footprint specification, therefore, exhibits better adherence with the residual normality assumption when compared to Model II(a). As a result, inferential properties of the model may be more stable.

The Breusch–Godfrey serial correlation tests give further information about the dynamic fit of the estimated models. The F-statistic value for Model II(a) is 2.458 and the probability value is 0.106, which is statistically insignificant. This means that there is no evidence to reject the null hypothesis of no serial correlation. The finding implies that the assumption of independence of residuals across time is reasonable and that the model is capturing the dynamic relationship between the explanatory variables is satisfactory. The absence of serial correlation means that the sample does not contain any systematic information which isn't explained by the model. Hence, the carbon emissions model seems to be a reasonably complete dynamic specification, and there is no omitted "lag" information content.

The pattern is quite different for Model II(b), however, from the results of the Breusch–Godfrey test. Table 7 shows the F-statistic of 7.343 and p value of 0.003 which are statistically significant at 1% level. Therefore, the null hypothesis is rejected, indicating that there is serial correlation. The result indicates that the residual values are serially correlated which implies that some dynamic structure was not fully identified with the specification that was estimated. From an economic point of view, the residuals will be serially correlated if there may be omitted lag structures, persistent dynamics or unobserved influences. This residual dependence can cause the inefficiency of estimating and influence the accuracy of the standard errors. Thus, there is a need for further selection methods for the lags in the ecological footprint model or for heteroskedasticity and autocorrelation consistent estimation techniques.

Table 7 shows the Breusch-Pagan test results for the heteroskedastic residual variance which suggest that both models have homoskedastic residual variance. The F-statistic for Model II(a) is 0.438 with probability value of 0.952 while that of Model II(b) is 0.685 with probability value of 0.777. The probability value for both sets is greater than the standard levels of significance, so that the null hypothesis of homoskedasticity may not be rejected. This finding suggests that residual variance is not systematically changing with changes in explanatory variables and is only relatively constant across observations. Heteroskedasticity is not desirable since it reduces estimation efficiency and makes the statistical inference less reliable. Therefore, both models fulfil the homoskedasticity assumption of the conditional mean equation.

The Durbin-Watson statistics are further evidence of residual dependence. The model II(a) gives a Durbin-Watson value of 2.380, which is relatively close to the value 2.0 recommended for the model. Econometrically, numbers around 2 mean that there is no 1st order auto-correlation in the data. This conclusion supports the Breusch-Godfrey result and shows that there is no significant time dependence in the residuals. For Model II(b), however, the value of the Durbin–Watson statistic is 0.975, well below the standard value. If the Durbin-Watson value is significantly less than two, then there is positive autocorrelation between residuals. This result is consistent with the findings of the Breusch-Godfrey test on serial correlation, and shows a sign of the residual persistence of the ecological footprint model.

In order to determine whether or not there is autoregressive conditional heteroskedasticity in the residual variance, the ARCH LM test was also applied. The ARCH statistics for Model II(a) is 0.597 and P-value is 0.444, which are considered to be statistically insignificant. So, we cannot reject the null hypothesis of no ARCH effects. That means that the shocks impact on carbon emissions do not cause volatility clustering over time and that conditional variance is stable. Model II(b) on the other hand, has an ARCH statistic of 3.421 and a probability value of 0.072, which is just slightly outside the 10% level of significance. The result indicates a low level of conditional heteroskedasticity and indicates that the disturbances of the ecological footprint might show mild volatility persistence. The ARCH evidence is not severe, however, it indicates that the intensity of the fluctuations in the ecological conditions may vary over time.

Table 7: Post-Estimation Diagnostic Tests – ARDL Models II(a) and II(b)

Diagnostic Test	F/Stat II(a)	p-value II(a)	F/Stat II(b)	p-value II(b)
Jarque-Bera (Normality)	17.3530	0.0002***	1.9818	0.3712
Breusch-Godfrey (Serial Corr., 2L)	2.4584	0.1060	7.3432	0.0031***
Breusch-Pagan (Heteroskedasticity)	0.4377	0.9517	0.6845	0.7770
Durbin-Watson	2.3799	—	0.9745	—
ARCH LM (Lag 1)	0.5967	0.4444	3.4205	0.0718*

*Note: *, **, *** denote significance at 10%, 5%, and 1% levels. H_0 for JB: residuals are normally distributed. H_0 for BG: no serial correlation (2 lags). H_0 for BP: homoskedastic residuals. H_0 for ARCH: no conditional heteroskedasticity (lag 1). DW values near 2.0 indicate absence of first-order autocorrelation.*

Parameter Stability Tests

CUSUM and CUSUM of squares tests for parameter stability over the sample period estimated are presented in Figures 2 and 3, respectively. These procedures test for structural stability of the estimated coefficients as they change over time. Structural stability is important in macroeconomic and environmental studies as unstable coefficients can reflect changing relationships between variables and weaken the validity of policy conclusions. The tests involve comparing recursive residuals with critical bounds at the 5% level of significance. In the event that the cumulative residual process falls inside of the critical limits, the null hypothesis of parameter stability cannot be rejected.

The recursive residual paths plotted in Figure 2 show that the residual paths are contained in the upper and lower critical bands for both Model II(a) and Model II(b) for the time period 1981-2024. This result suggests that there are no structural breaks or coefficient instability over the estimation period. From an econometric perspective, parameter constancy suggests that the effects of urbanisation and institutional quality, and how these variables interact, on environmental degradation are stable over time, even in the presence of varying political regimes, macroeconomic conditions and policy environments. In this case the estimated coefficients can be taken as structurally reliable to be interpreted in the long run and used for policy recommendations.

Likewise, the CUSUM of Squares plots are shown in Figure 3 to assess the stability of the variance of residuals. For both models, the recursive variance paths are bounded within the specified limits over the sample period. The recursive variance paths stay within the specified limits over the sample period for both models. This is a good sign of stable variance behaviour and lack of sudden structural changes in residual volatility. Thus, the stability evidence further corroborates the previous CUSUM results and enhances the confidence level on the robustness of the estimated ARDL coefficients. Thus, Figures 2 and 3 provide strong evidence of relatively stable environmental relationships across time and for sound policy inferences.

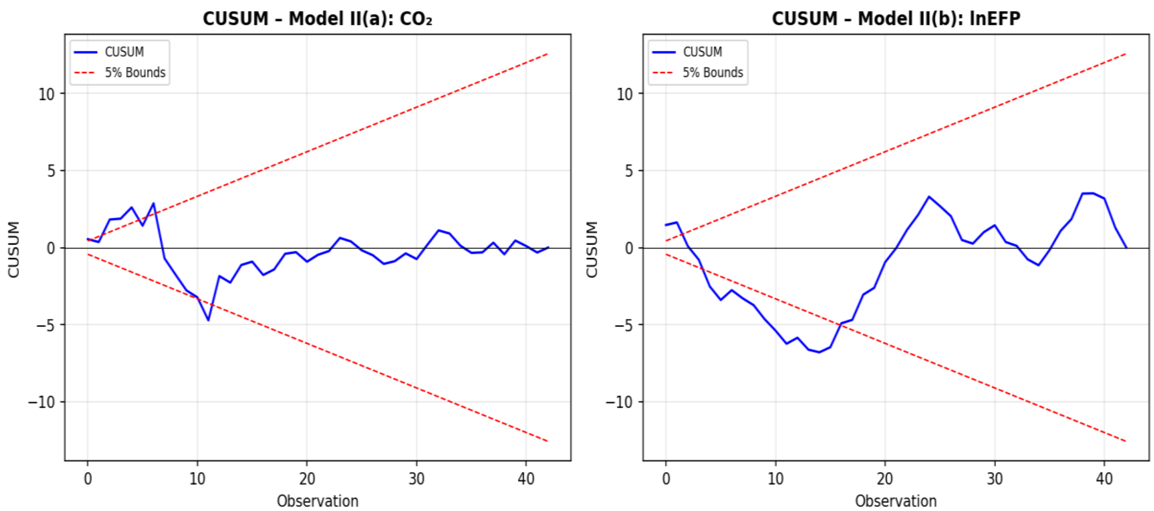

Figure 2: CUSUM Test for Parameter Stability – Models II(a) and II(b)

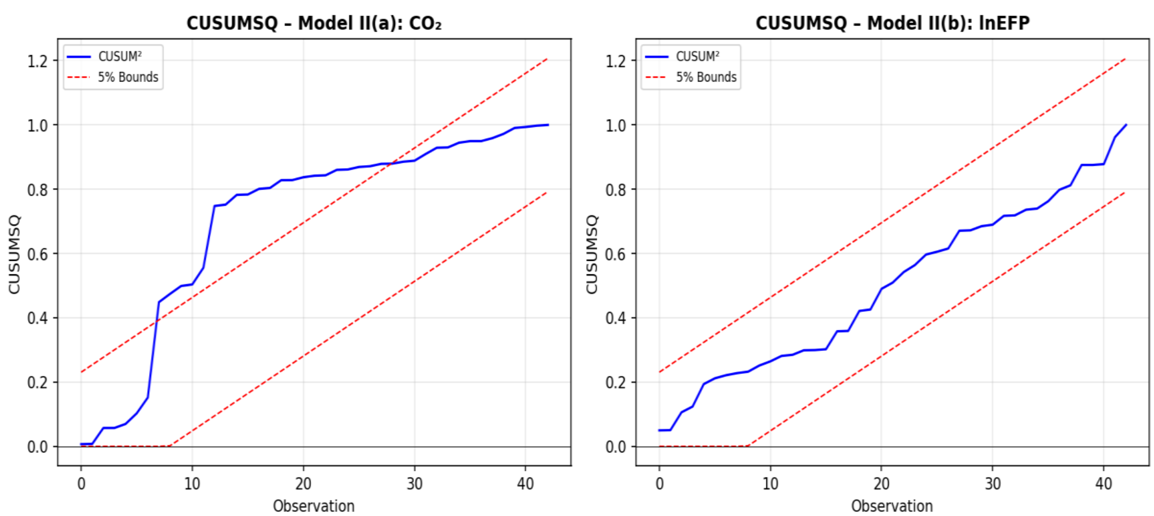

Figure 3: CUSUM of Squares Test for Parameter Stability – Models II(a) and II(b)

Residual Diagnostics

The residual plots and normal Q-Q plots of the estimated ARDL models are shown in Figure 4. The residual plots are used for visual evidence of specification adequacy and omitted variables and possible nonlinear patterns. Ideally, residuals will be normally distributed, have no systematic patterns and no systematic trends. The residual plots for Model II(a) show little pattern and appear to be about evenly distributed. This trend implies that the model is a good fit for the data-generating process and that relevant information explaining the data isn't missing.

The residual plots for Model II(b), however, show some pattern of the data within certain periods. The clustering can suggest dependency structure for the residual process, and matches with the serial dependency observed in Table 7. The normal Q-Q plots give further evidence on the distributional properties of the residuals. In the case of Model II(a), the observations are mostly in line with the theoretical line, with slight deviations seen at the tails, which supports the results of the Jarque-Bera test. In contrast, the Q-Q plot for Model II(b) is more similar to the theoretical normal line, and the residual normality is not rejected. Thus, Figure 4 indicates the overall suitability of the estimated specifications and reiterates the previous diagnosis on residual behaviour.

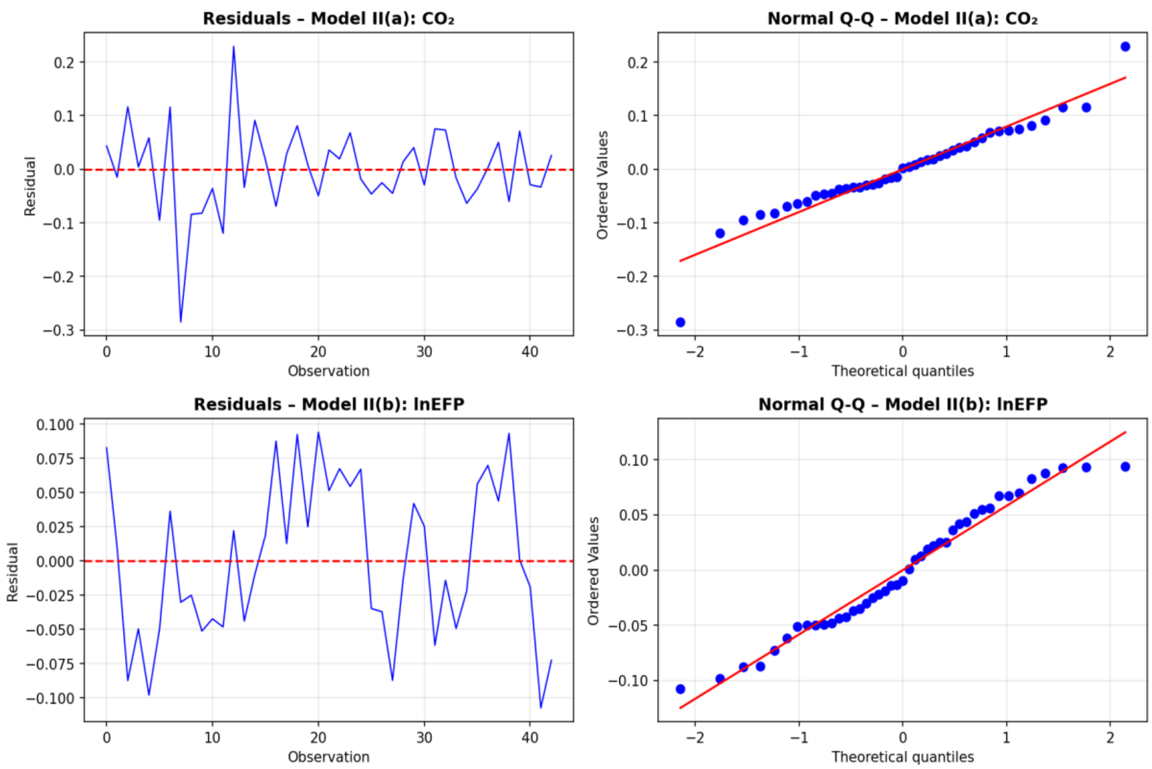

Figure 4: Residual Diagnostics – ARDL Models II(a) and II(b)

Discussion of Findings

The empirical findings provide strong support for the institutional moderation hypothesis that the higher the level of institutional quality, the lower the marginal environmental impact of urbanisation in Nigeria. This finding corroborates the Institutional Theory and agrees with Dada & Ajide (2021), Maduka et al. (2022), Abaidoo & Agyapong (2023), Daghbagi et al. (2025) and Farah et al. (2026) that governance quality plays a positive moderating effect between the environmental impacts of economic activity. Results obtained from ARDL, FMOLS, and DOLS using three estimators significantly boost the confidence on the moderating mechanism and tackle the issue of endogeneity. Coefficients are directionally consistent and between 10 and 20% of the same size, pointing to the fact that the institutional moderation finding is not an artefact of the assumptions made in the estimation.

As expected, the direct link of the institutional quality ($\gamma_2 < 0$) suggests that the improvement of institutions in itself has a significant negative effect on the degradation of the environment. This discovery is in contrast to the result obtained by Mohamed et al., (2025) for Somalia where the institutional quality was not directly affected at all which may be attributed to the more developed institutional infrastructure in Nigeria when compared to the fragile state contexts. As established in Section 4.5, the threshold analysis further reveals an asymmetric risk profile: governance deterioration magnifies urbanisation's environmental impact more sharply than equivalent governance improvements attenuate it, underscoring the disproportionate cost of institutional erosion for Nigeria's sustainability path.

CONCLUSION

This paper, through an empirical approach, found that the relationship between urbanisation and environmental degradation is significantly moderated by institutional quality in Nigeria. The study finds that better governance quality lowers the marginal environmental impact of urban sprawl (weak institutions increase the costs), using interaction-based ARDL model validated by the FMOLS and DOLS long-run estimators. The direct impact of institutional quality on environmental degradation is found to be also negative and significant: institutional quality improvements themselves reduce CO_2 emission and ecological footprint.

Convergence of three long-run estimators offers solid evidence that the institutional moderation finding is not estimator specific. The elasticity of urbanisation and CO_2 at the current average level of institutional quality in Nigeria is about 0.84, which is well above the elasticity under optimal institutional quality (~0.64) and well below the elasticity under poor institutional quality (~1.01). This is a very large policy-relevant leverage point for environmental governance reform.

RECOMMENDATIONS

Based on the foregoing findings, the study suggests that Nigeria needs to urgently build up the capacities of the environmental governance institutions such as NESREA, National Environmental Management Agency, and state environmental protection agencies with financial resources, qualified personnel, and administrative autonomy. There is need to fully implement the Climate Change Act 2021 through effective institutional implementation mechanisms. Second, interventions to counter corruption and accountability mechanisms are crucial, as research shows that poor institutional quality disproportionately exacerbates the environmental impacts. Third, it is important to build up urban planning institutions to ensure environmentally sustainable urban development standards, in order to minimize the environmental impacts of urban sprawl. These recommendations are a direct contribution towards SDG 13 (Climate Action) and SDG 16 (Strong Institutions).

Limitation to the Study

Notwithstanding these contributions, the study acknowledges that its inferences are constrained by the availability of annual national-level time-series data and by measurement uncertainty inherent in ecological footprint estimates; future research employing sub-national panel data or higher-frequency series would enrich causal identification, and the institutional moderation framework advanced here is directly transferable to other resource-pressured developing economies across Sub-Saharan Africa.

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